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Atlas of TOMS Ozone Data Collected During the Genesis of Atlantic Lows Experiment (GALE), 1986

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INTRODUCTION

The field phase of the GALE (Genesis of Atlantic Lows Experiment) covered the period January 15, 1986 through March 15, 1986. As part of this experiment, data from the TOMS (Total Ozone Mapping Spectrometer) instrument aboard the sun-synchronous polar-orbiting Nimbus-7 satellite were collected daily in real-time. Two to three orbital passes per day covered the GALE area (west-central U.S. through the western Atlantic Ocean and the Gulf of Mexico through south-central Canada). The overpass data were processed in real-time on a per-orbit basis as they became available every day during the GALE project. Each overpass occurs at approximately local noon (plus or minus one hour) at any given location and covers a horizontal area of approximately 30 degrees of longitude. This atlas provides individual objectively analyzed contour maps of the ozone from TOMS for each of the sixty days during GALE. Four-panel presentations of the same ozone analyses are combined for the Intensive Observing Periods (IOP's) conducted during GALE. A summary of the days and times of the 13 GALE IOP's can be found in Table 1. The maps should provide an overview of the evolution of ozone patterns during the GALE period and alert researchers as to the data availability for each IOP.

DATA ACQUISITION AND TRANSFER

The path of the real-time data flow and transfer during GALE is illustrated in Figure 1. The raw TOMS data from each orbital overpass over the GALE area were collected daily at the

Table 1. List of the GALE Intensive Observing Periods (IOP's) which occurred during the field program in 1986.

IOP No.	Start Date and Time	End Date and Time	Total Time of IOP
1	18 January 00Z	20 January 21Z	65 hours
2	23 January 12Z	29 January 04Z	136 hours
3	2 February 18Z	4 February 23Z	53 hours
4	6 February 07Z	8 February 00Z	41 hours
5	9 February 00Z	13 February 23Z	119 hours
6	14 February 00Z	15 February 17Z	41 hours
7	21 February 12Z	22 February 06Z	18 hours
8	22 February 17Z	24 February 01Z	32 hours
9	24 February 18Z	26 February 19Z	49 hours
10	27 February 00Z	28 February 12Z	36 hours
11	28 February 21Z	2 March 21Z	48 hours
12	6 March 17Z	9 March 21Z	76 hours
13	11 March 17Z	15 March 00Z	79 hours

Mission Operations Control Center (MOCC) in Building 3 at the Goddard Space Flight Center (GSFC) and placed onto magnetic tape. This tape was then manually transferred to the NASA Space and Earth Sciences Computing Center (NSESCC) in Building 1 at GSFC where the raw data on the tape was processed into total ozone data on an IBM 3081 computer. The resultant total ozone and reflectivity data were tagged with a date and time of observation plus a latitude and longitude location and placed onto a disk on the IBM 3081. This disk file was then transferred via direct communication link to the Interactive Astronomical Data Analysis Facility (IADAF) on a VAX 11/750 in Building 21 at GSFC. The disk file was then transmitted over a 1200 baud telephone line utilizing VAXNET from Building 21 to a VAX 11/780 located at the Atmospheric and Oceanographic Information Processing System (AOIPS) in Building 22 at GSFC. This disk file was then processed on the VAX 11/780 and the resultant disk dataset was transferred to a MicroVAX-II located at GALE Operations at the Raleigh-Durham, N.C. airport over a dedicated 9600 baud telephone line utilizing DECnet. The TOMS dataset was then used at GALE Operations as an indicator of the location and intensity of upper-level troughs and to direct aircraft research flights recording *in situ* measurements of ozone and water vapor in areas of interest.

At best, the total time from data acquisition to processed dataset on disk at GALE Operations was three hours. The average time for complete data transfer was on the order of four to five hours. There were a few occasions when the raw data, for one reason or another, was not available in real-time which necessitated playback of the orbital overpass the following day. On these occasions, the playback data were processed and sent to GALE Operations as soon as it became available. There were also times that the electronic communication links described above at GSFC were unavailable. This would slow down the total processing time as tape copies of the disk datasets and manual transport from computer to computer would have to be substituted in place of the electronic transfer method. For the most part, especially

during IOP's, the transfer system worked adequately to have the ozone data at GALE Operations in time to be useful for real-time applications.

DATA ANALYSIS AND PRESENTATION

The first processing that is done is to convert the raw TOMS data into ozone data values. This processing is done on the IBM 3081 and results in a card image disk file of the total ozone observations in Dobson units (where a Dobson unit corresponds to a milli-atmosphere centimeter) and reflectivity in percent, time tagged and located by latitude and longitude. These observations are then converted into GEMPAK format on a VAX 11/780 as a GEMPAK dataset with the ozone and reflectivity stored as single-level "surface" data along with their respective latitude and longitude location. This conversion into GEMPAK format allows the use of associated GEMPAK-GEMPLT routines to conveniently and rapidly plot the individual observations on a map from the GEMPAK dataset (see desJardins and Petersen 1985). These GEMPAK datasets of the ozone and reflectivity were sent on an orbit-by-orbit basis to GALE Operations for display and analysis in Raleigh-Durham N.C. Furthermore, having the ozone data in this format allows for easy access and use of GEMPAK routines to perform an objective analysis of the data. The result of the objective analysis is a file of the ozone and/or reflectivity data interpolated to a regularly spaced latitude-longitude grid which then can be run through GEMPAK-GEMPLT routines to produce contour maps of the ozone and/or reflectivity.

For this atlas, the individual ozone observations were extracted from four to five orbits per day of the GALE period, over the region from 18.4 through 60.6 degrees north latitude and from 44.9 through 127.1 degrees west longitude. An example of the coverage is shown for the January 20 ozone observations in Figure 2. Because of data storage limitations in the GEMPAK routines, only every third scan and every third sample in the

scans selected were extracted. The selected observations for one day were then objectively analyzed as one dataset using the GEMPAK Barnes objective analysis routine (see Koch *et al* 1981). The average station spacing chosen was 2.0 degrees, the grid spacing in longitude was 1.5 degrees, and the grid spacing in latitude was 1.0 degrees with a numerical convergence parameter of 0.75. The grid area selected covered 20.0 through 59.0 degrees north latitude and 47.0 through 125.0 degrees west longitude resulting in a grid dimension of 53 by 40 cells. These values were selected to produce relatively smooth analyses of the TOMS data. However, the use of these analysis parameters could eliminate some of the mesoscale features in the TOMS data which may be significant. If all of the observation data were used and objectively analyzed to a smaller grid with a stronger numerical convergence parameter, maximum detail of the ozone features could be retained if desired.

Figures 3, 4, 5, and 6 illustrate the degree of mesoscale structure which can be retained or lost depending on the choice of the objective analysis parameters. Figure 3 shows the complete original ozone sample data available from a portion of the east-coast orbit on January 20. An objective analysis was performed on this dense data coverage using an average station spacing of 0.5 degrees, a longitude grid spacing of 0.4 degrees, and a latitude grid spacing of 0.25 degrees with the numerical convergence parameter set to 0.3. A contour plot of this grid was made using contour at every 10 Dobson units and is shown in Figure 4. The data density which is commensurate with that used in the atlas that follow is shown for the same portion of the orbit on January 20 in Figure 5. This subsetted dataset was then objectively analyzed as described above. The ozone contour plot resulting from this grid is shown in Figure 6.

The smoother grids of the total ozone covering a larger domain are presented on analyses contoured every 10 Dobson units on a Lambert conical projection. This atlas contains one contour total ozone map for each day of the GALE project period

(January 15 through March 15, 1986) presented in Figures 7 through 66. In addition, 12 four-panel ozone maps are presented in Figures 67 through 78. Each four-panel presentation covers half, one, or two of each of the GALE IOP's in order to provide an overview of the total ozone pattern and its evolution during the entire IOP.

ACKNOWLEDGEMENTS

Dr. James C. Dodge, head of NASA Headquarters Mesoscale Atmospheric Processes Research Program, provided support for the collection, distribution, and archive of the TOMS data. Thanks goes to Dr. Dennis Chesters of NASA/GSFC for his review of the manuscript and figures and for his suggestions and contributions to this paper and to Mr. Wayne Robinson of General Sciences Corporation for his assistance in the processing of the real-time ozone during the last two weeks of February. A note of appreciation goes to Messrs. Frank Keefer and Daniel Klinglesmith of NASA/GSFC for their cooperation and help in allowing us to use the VAX 11/750 to retrieve the card image disk datasets of ozone from the IBM 3081. We would also like to thank Ms. Mary DesJardins of NASA/GSFC and the GEMPAK team of Messrs. Ira Graffman and H. Michael Goodman of Research and Data Systems, Inc. for their assistance and cooperation before, during, and after GALE in the use of GEMPAK for this particular project.

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Koch, S. E., M. desJardins, and P. J. Kocin, 1981: The GEMPAK Barnes Objective Analysis Scheme. *NASA Technical Memorandum TM-83851.* Goddard Space Flight Center, Greenbelt, MD, 56 pp.

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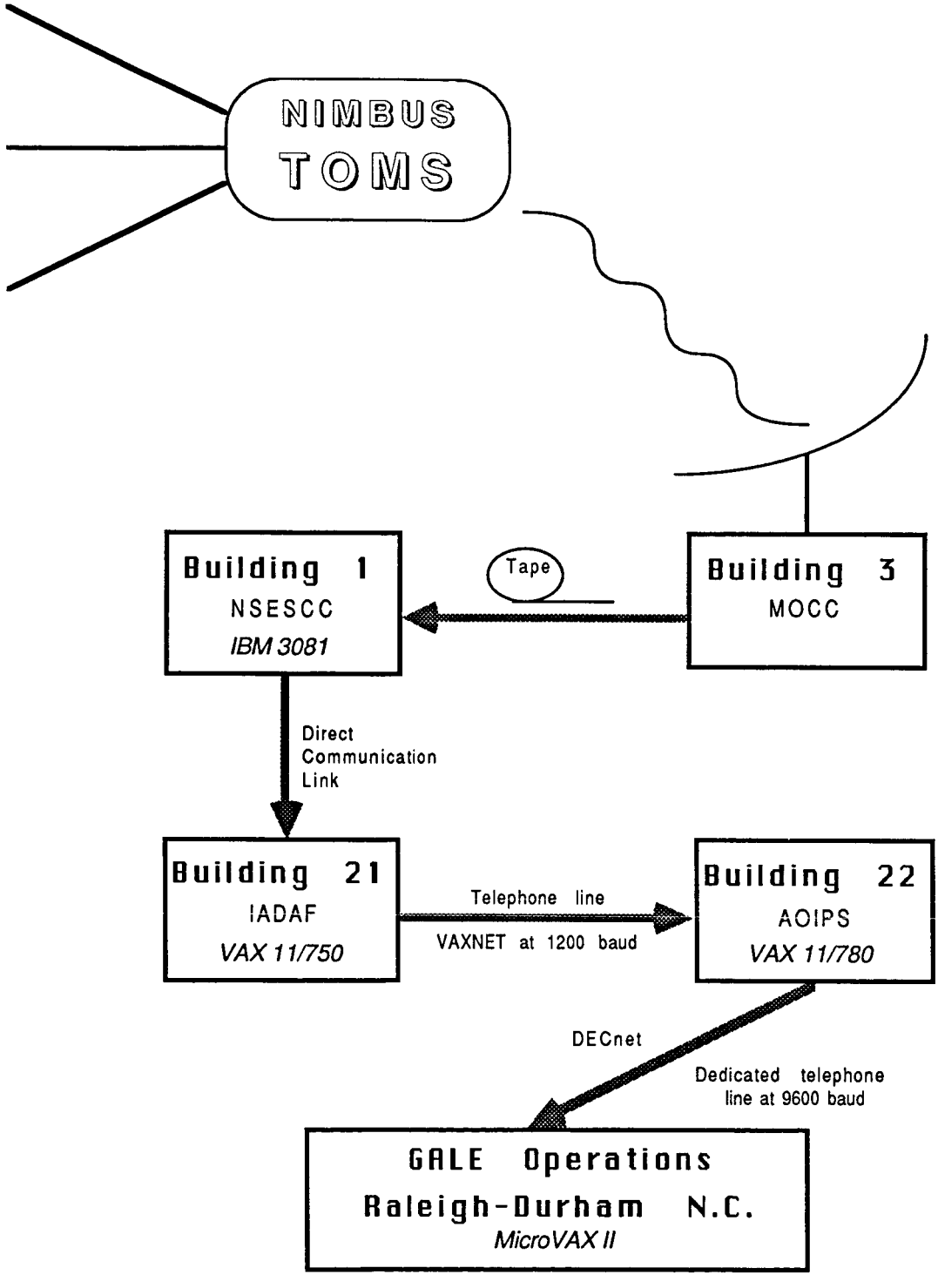

Figure 1. Real-time TOMS data path during the GALE period.

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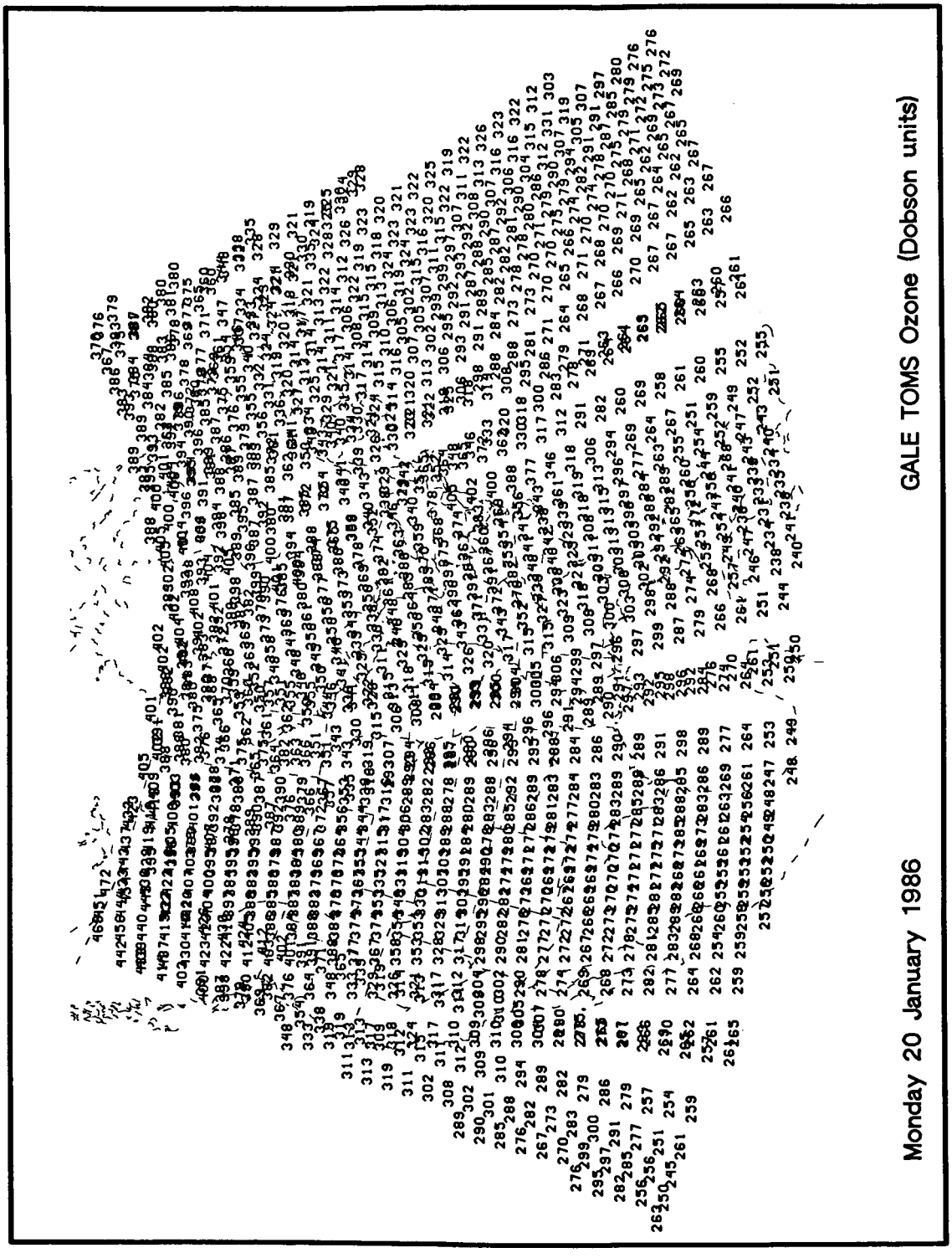

Figure 2. Map of individual ozone observations for Monday, 20 January 1986 showing every third scan and every third sample for portions of five orbits over the U.S.

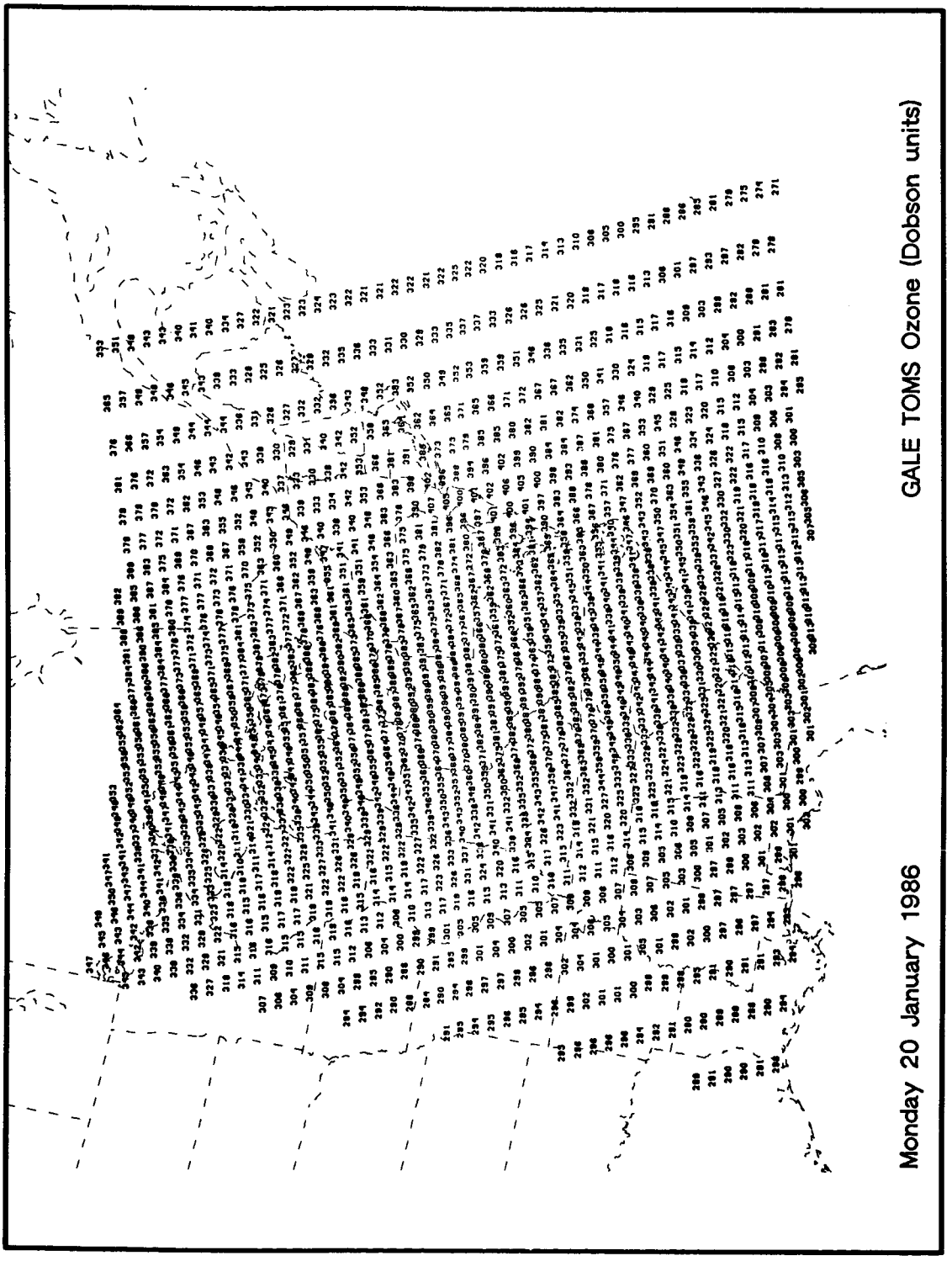

Figure 3. Map of individual ozone observations for Monday, 20 January 1986 showing every scan and every sample in each scan for a portion of one orbit over the eastern U.S.

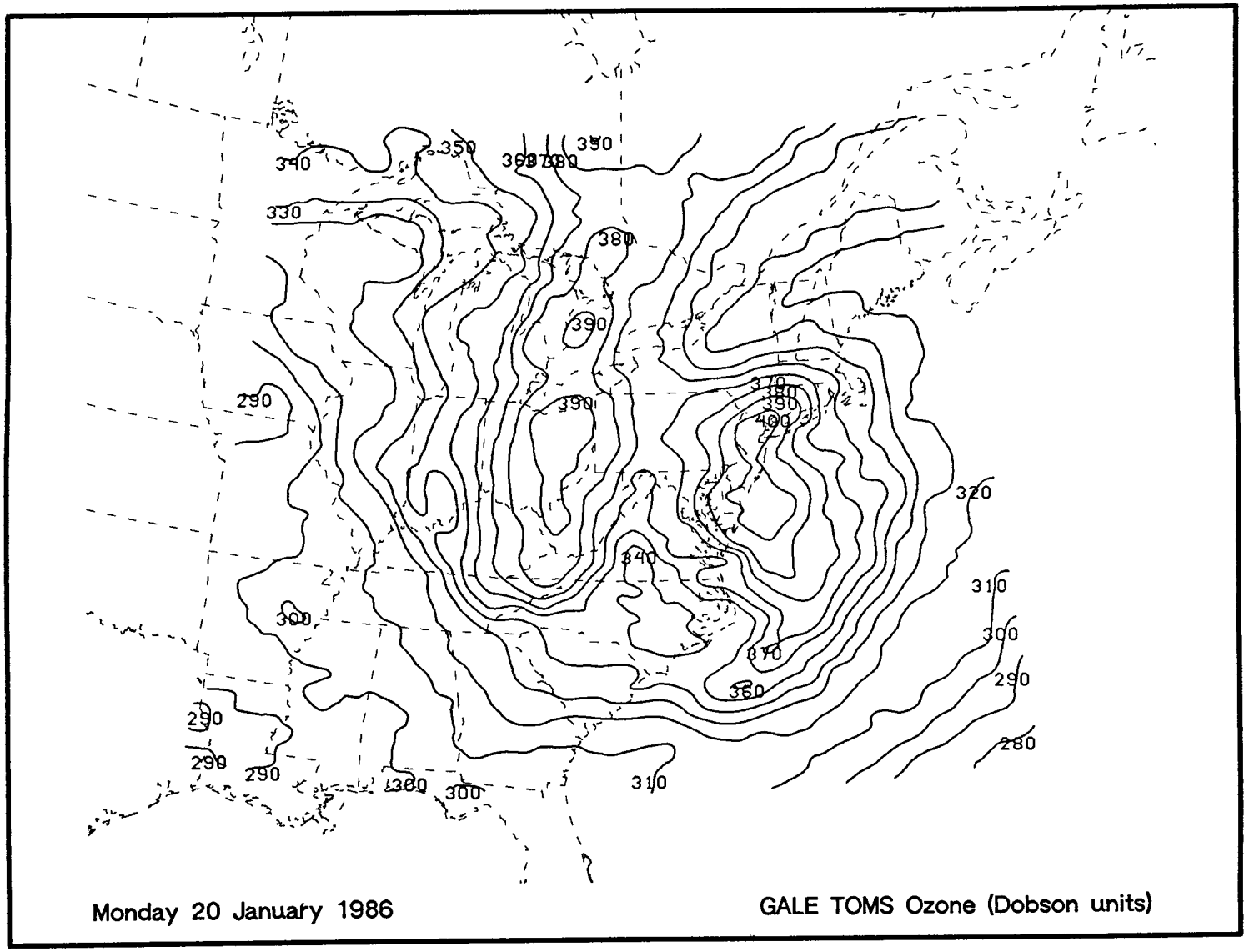

Figure 4. Ozone contour map (ten Dobson unit intervals) for Monday, 20 January 1986 based on dense grid from data shown in Figure 3.

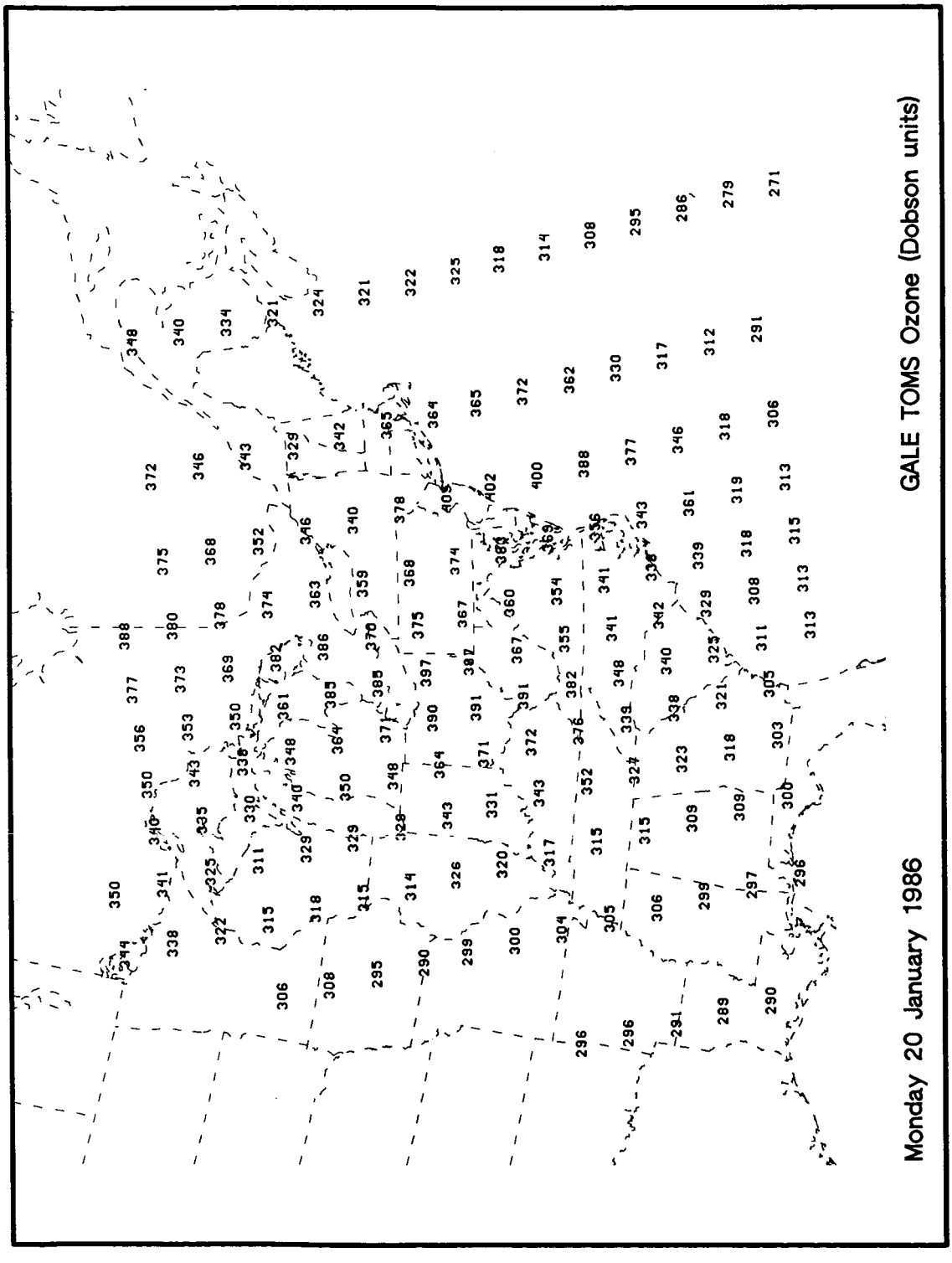

Figure 5. Map of individual ozone observations for Monday, 20 January 1986 showing every third scan and every third sample for a portion of one orbit over the eastern U.S.

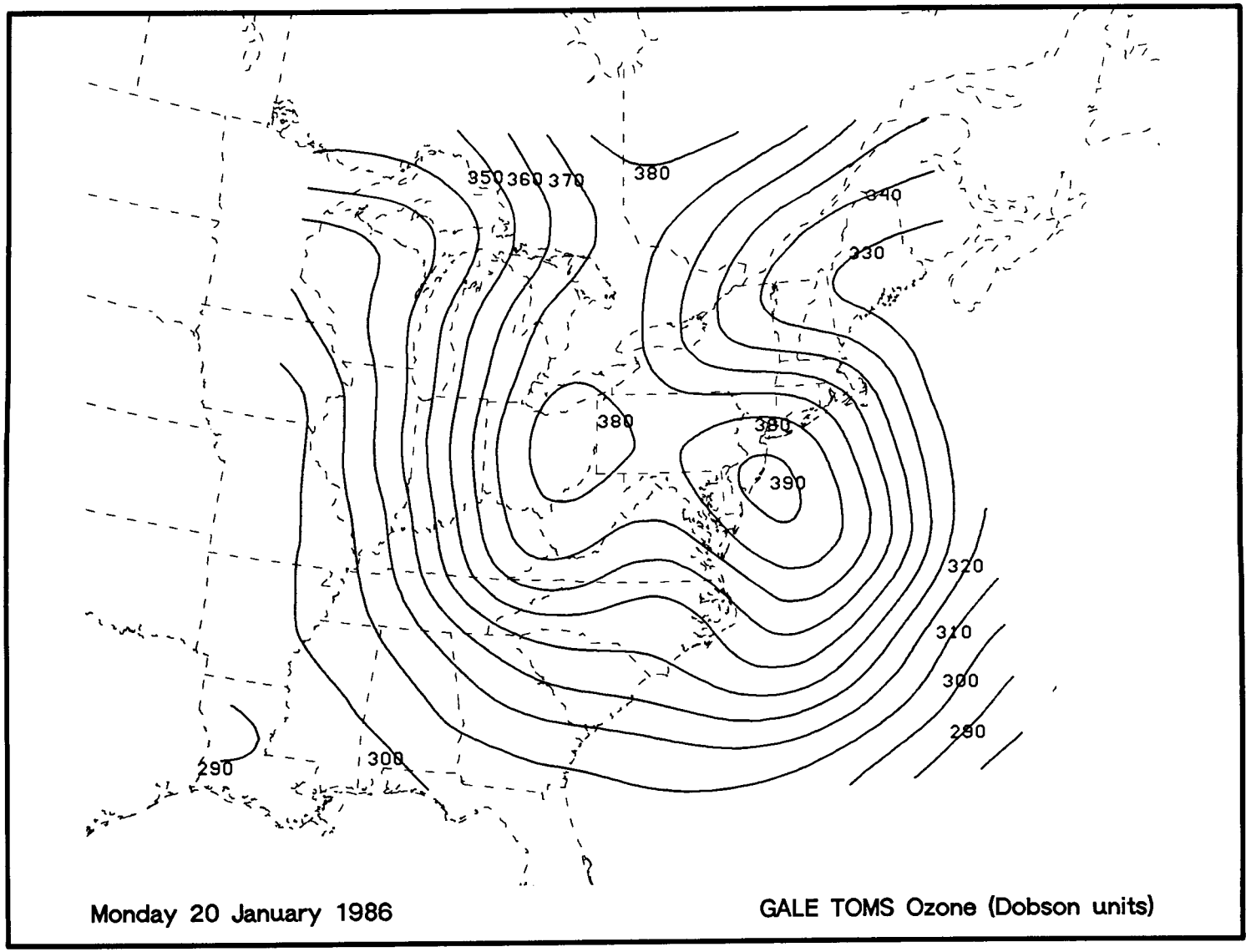

Figure 6. Ozone contour map (ten Dobson unit intervals) for Monday, 20 January 1986 based on under-sampled grid from data shown in Figure 5.

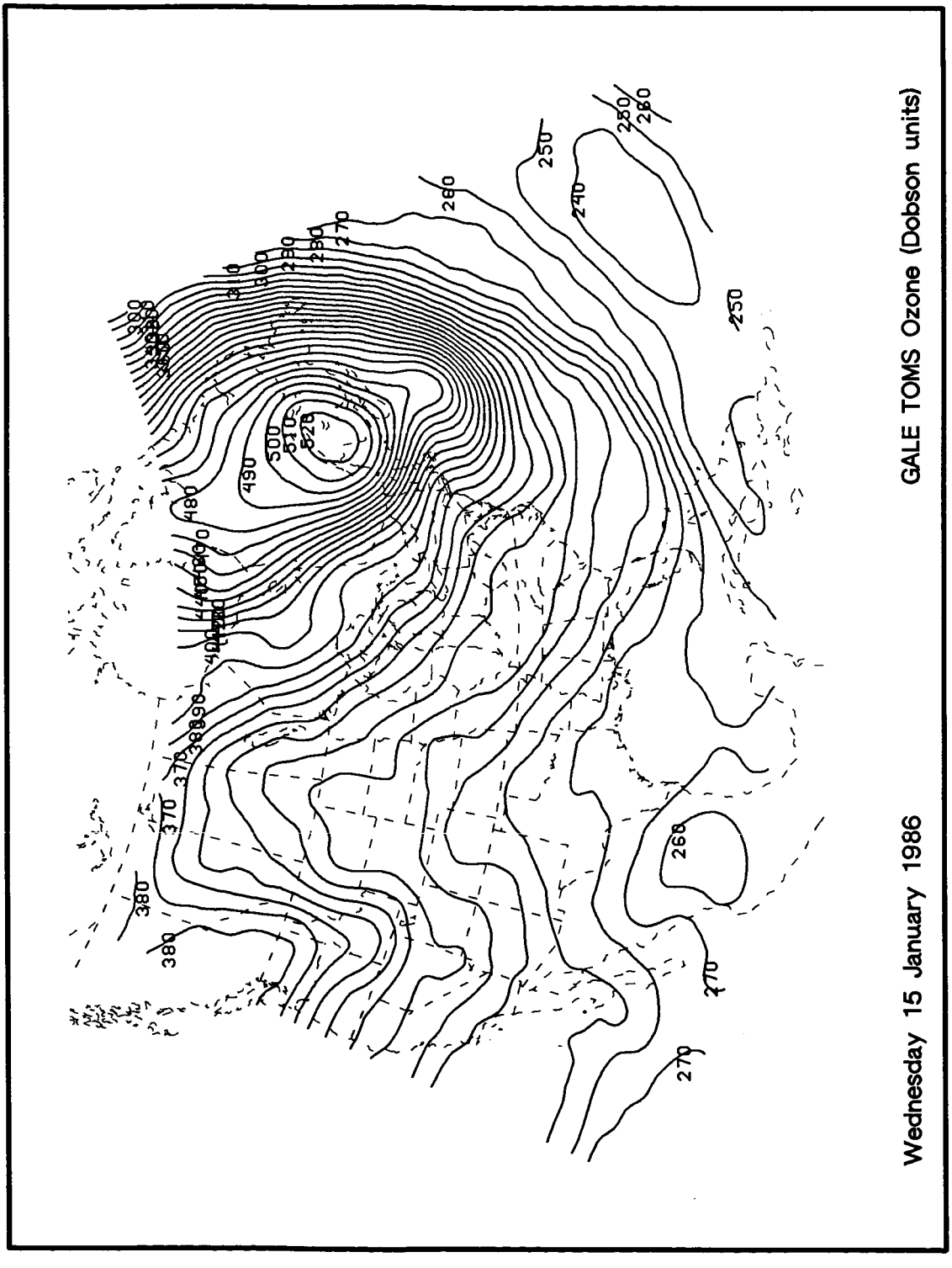

Figure 7. Ozone contour map (ten Dobson unit intervals) for GALE Day 1 Wednesday, 15 January 1986.

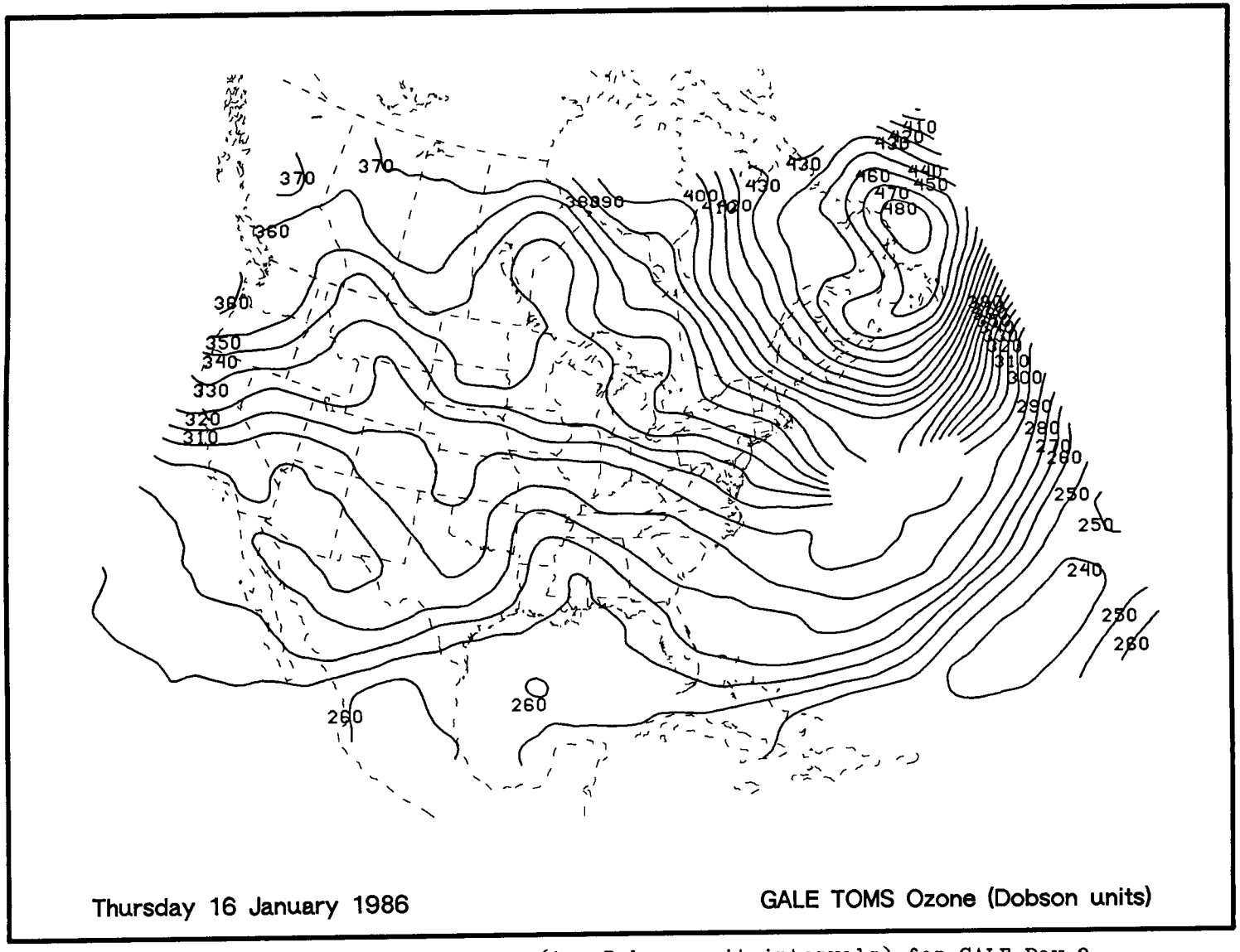

Figure 8. Ozone contour map (ten Dobson unit intervals) for GALE Day 2 Thursday, 16 January 1986.

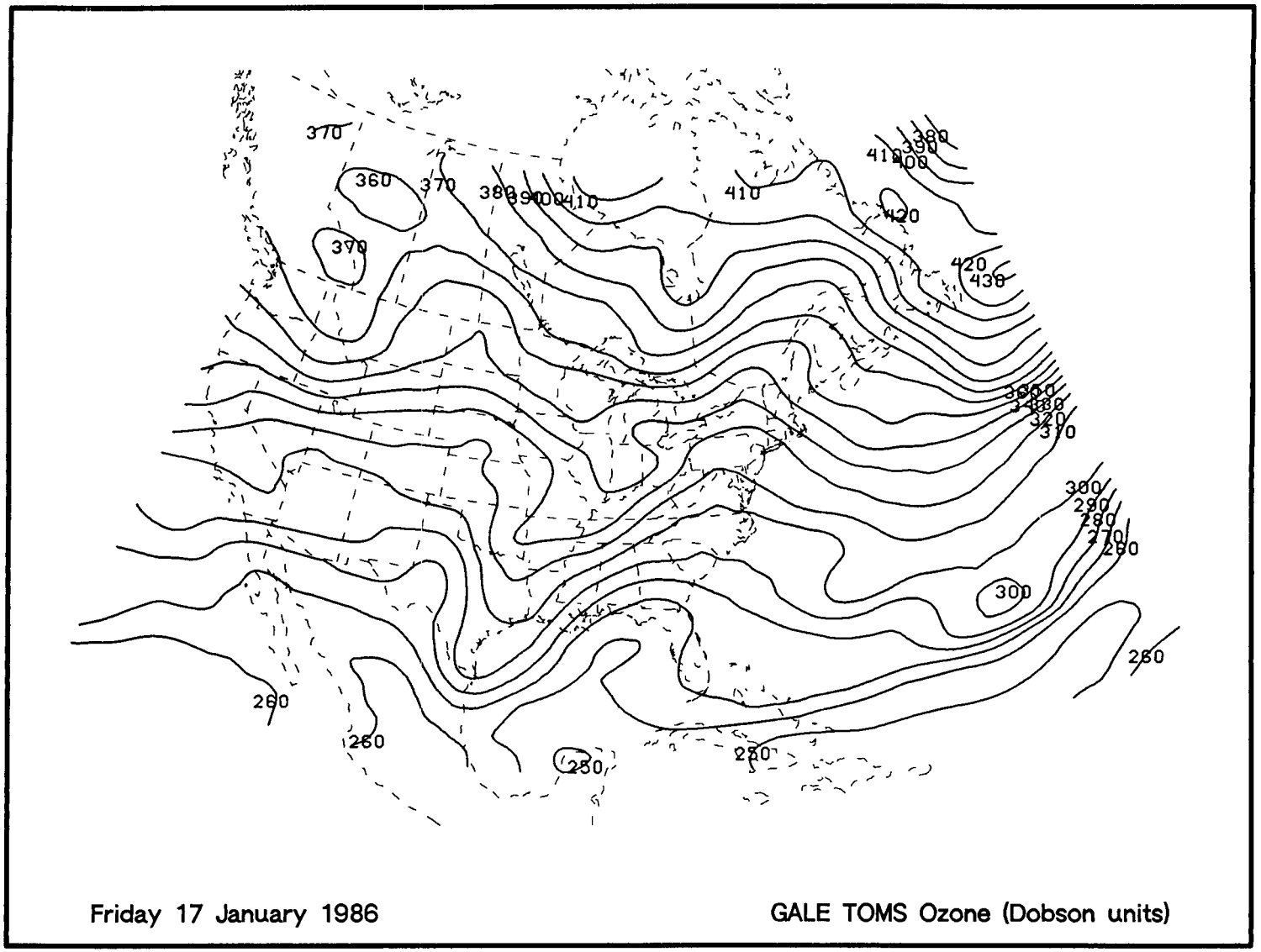

Figure 9. Ozone contour map (ten Dobson unit intervals) for GALE Day 3 Friday, 17 January 1986.

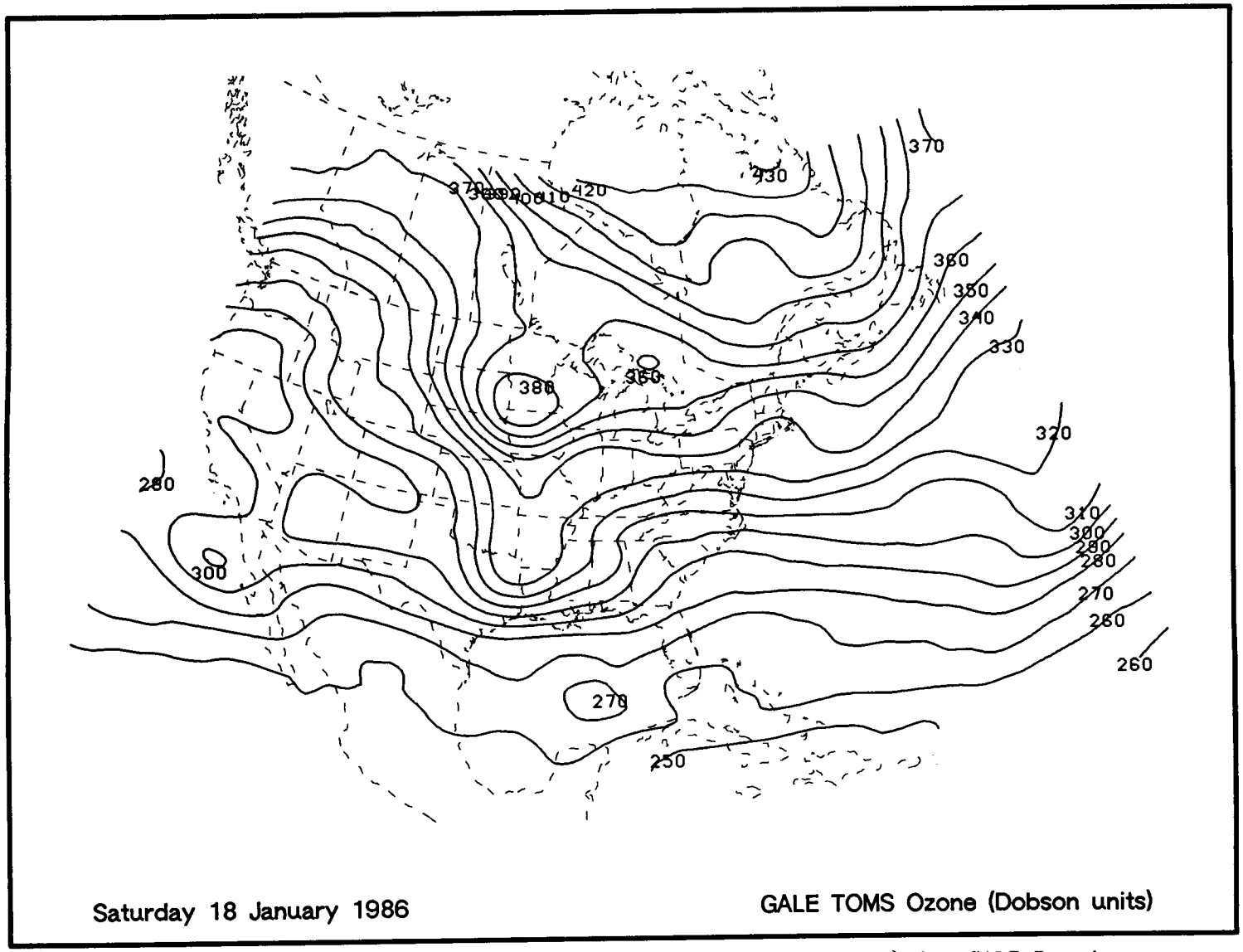

Figure 10. Ozone contour map (ten Dobson unit intervals) for GALE Day 4 Saturday, 18 January 1986.

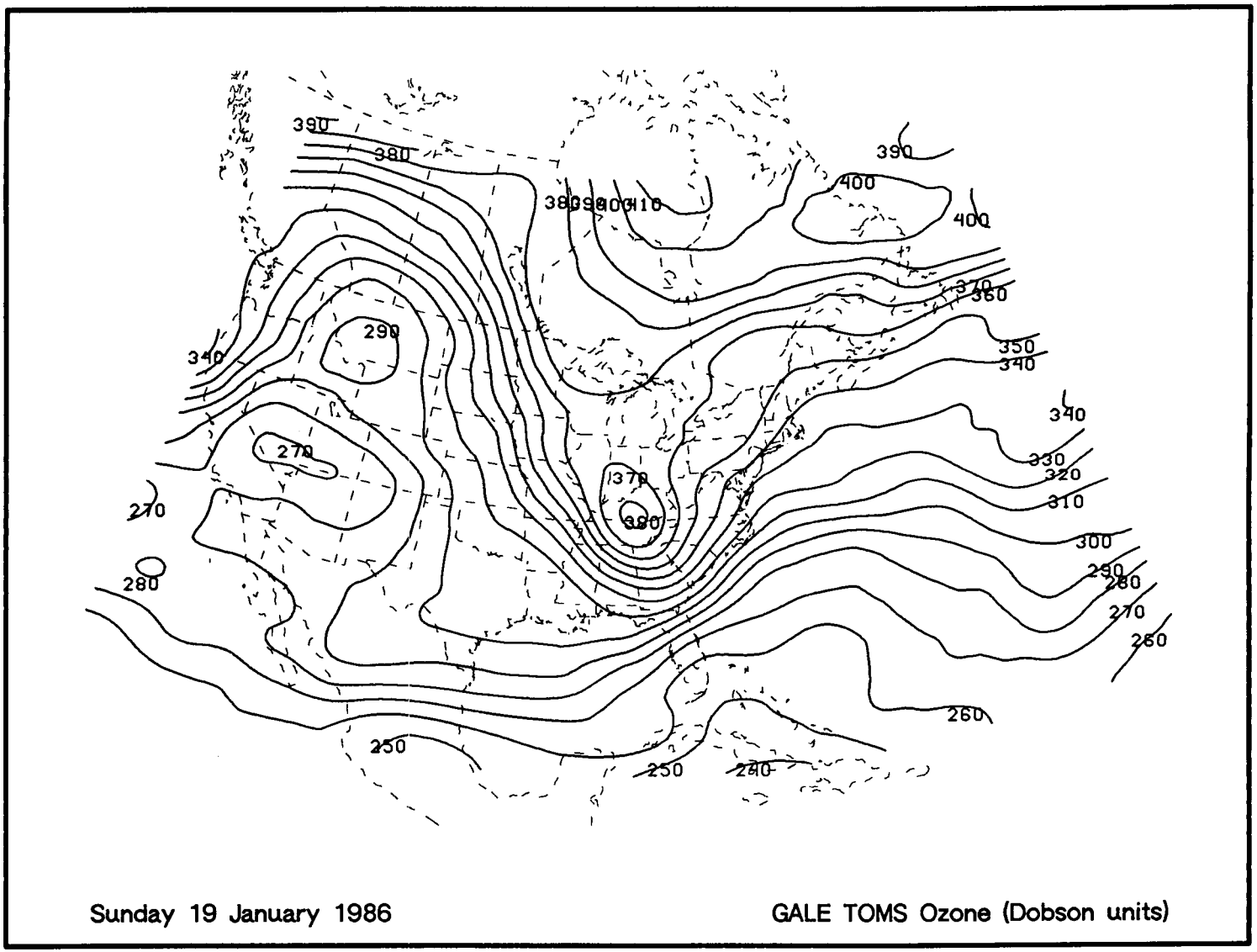

Figure 11. Ozone contour map (ten Dobson unit intervals) for GALE Day 5 Sunday, 19 January 1986.

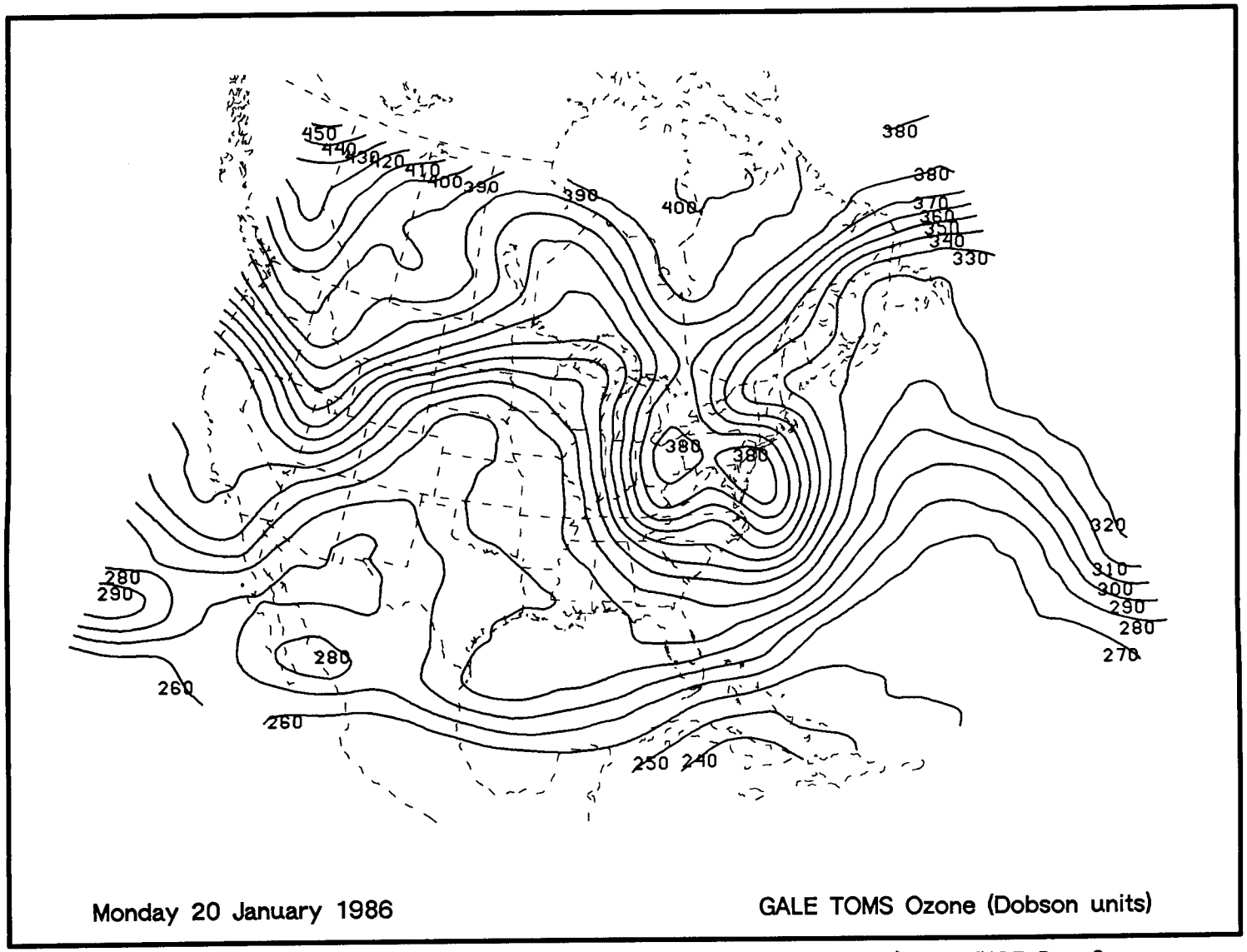

Figure 12. Ozone contour map (ten Dobson unit intervals) for GALE Day 6 Monday, 20 January 1986.

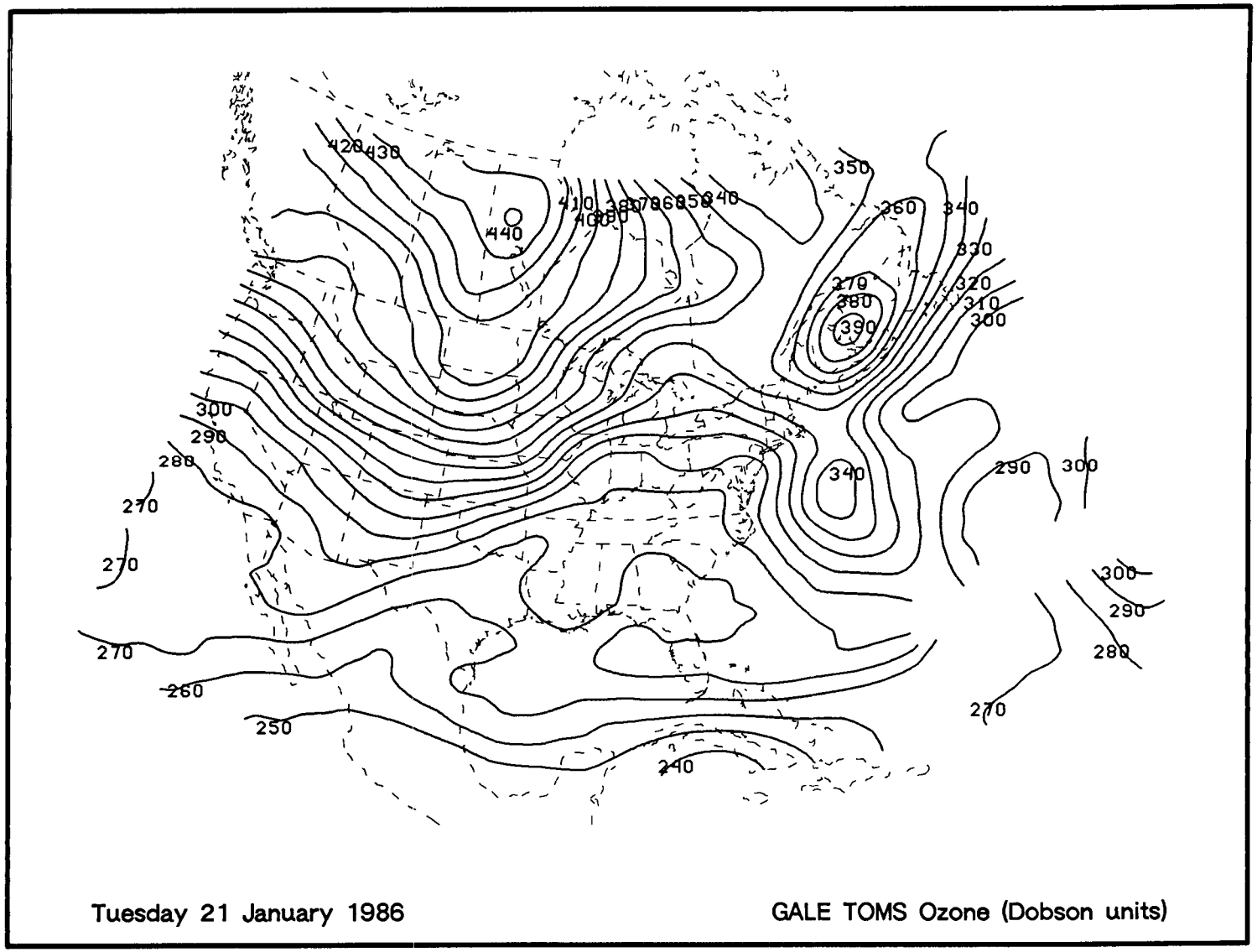

Figure 13. Ozone contour map (ten Dobson unit intervals) for GALE Day 7 Tuesday, 21 January 1986.

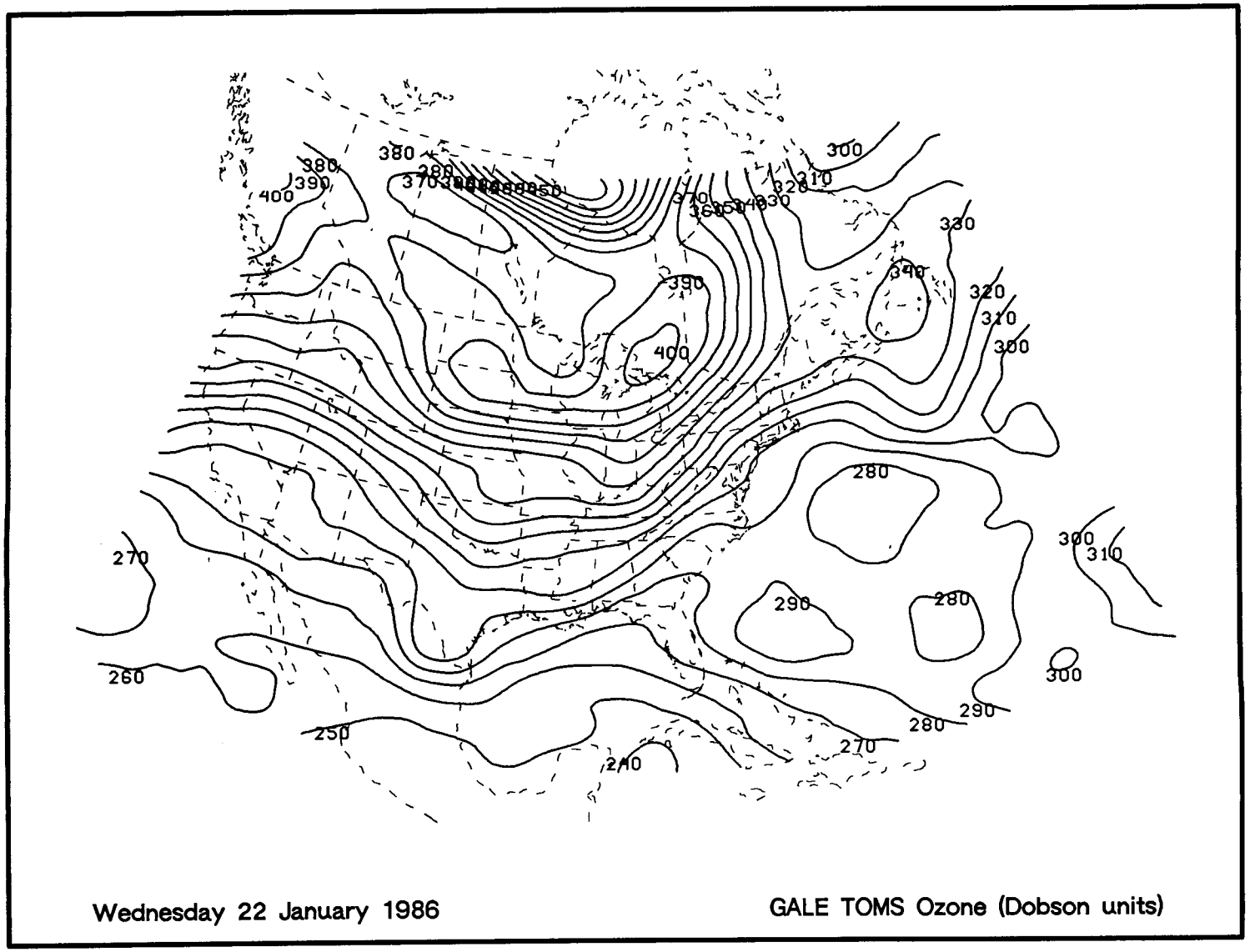

Figure 14. Ozone contour map (ten Dobson unit intervals) for GALE Day 8 Wednesday, 22 January 1986.

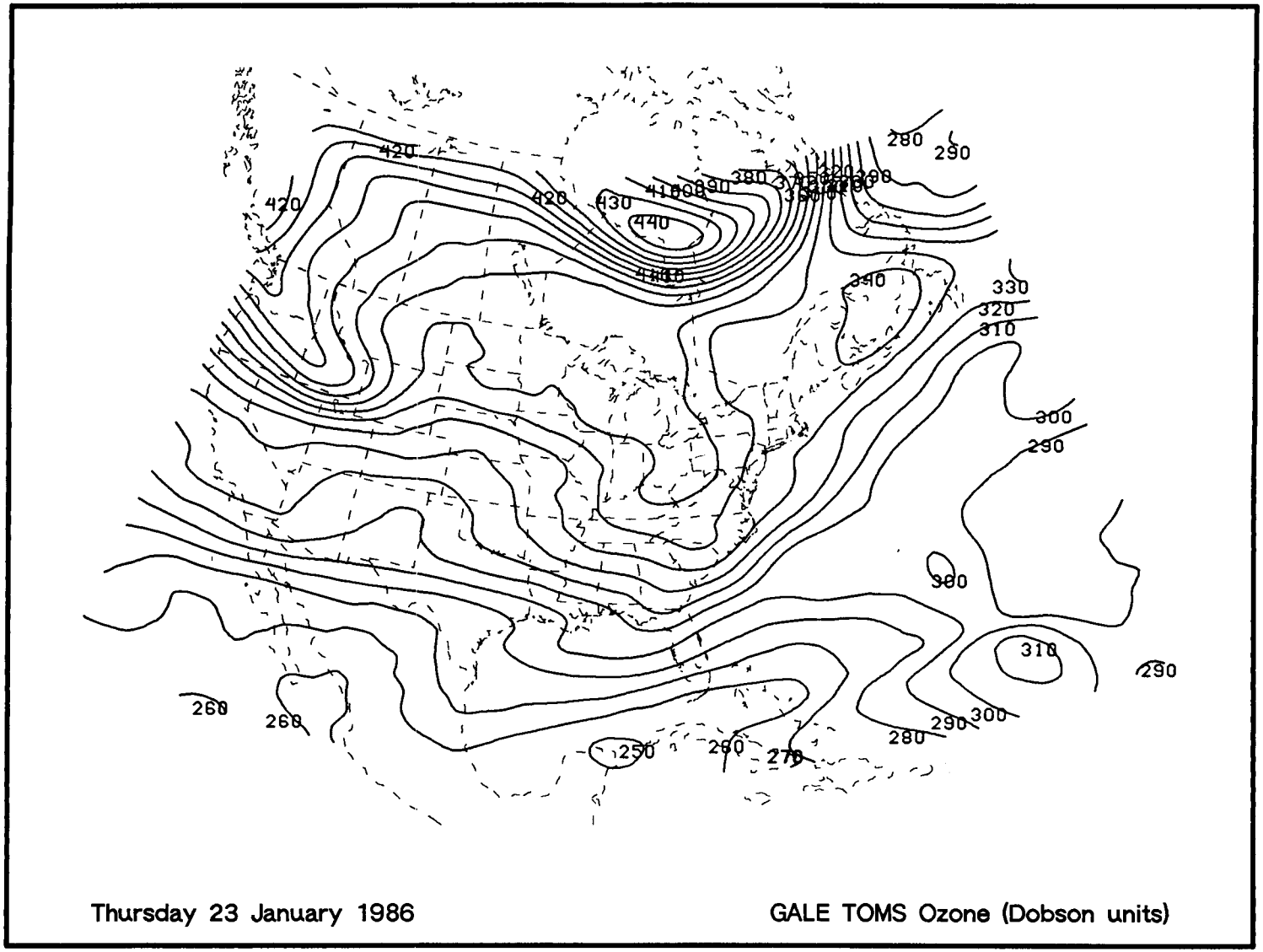

Figure 15. Ozone contour map (ten Dobson unit intervals) for GALE Day 9 Thursday, 23 January 1986.

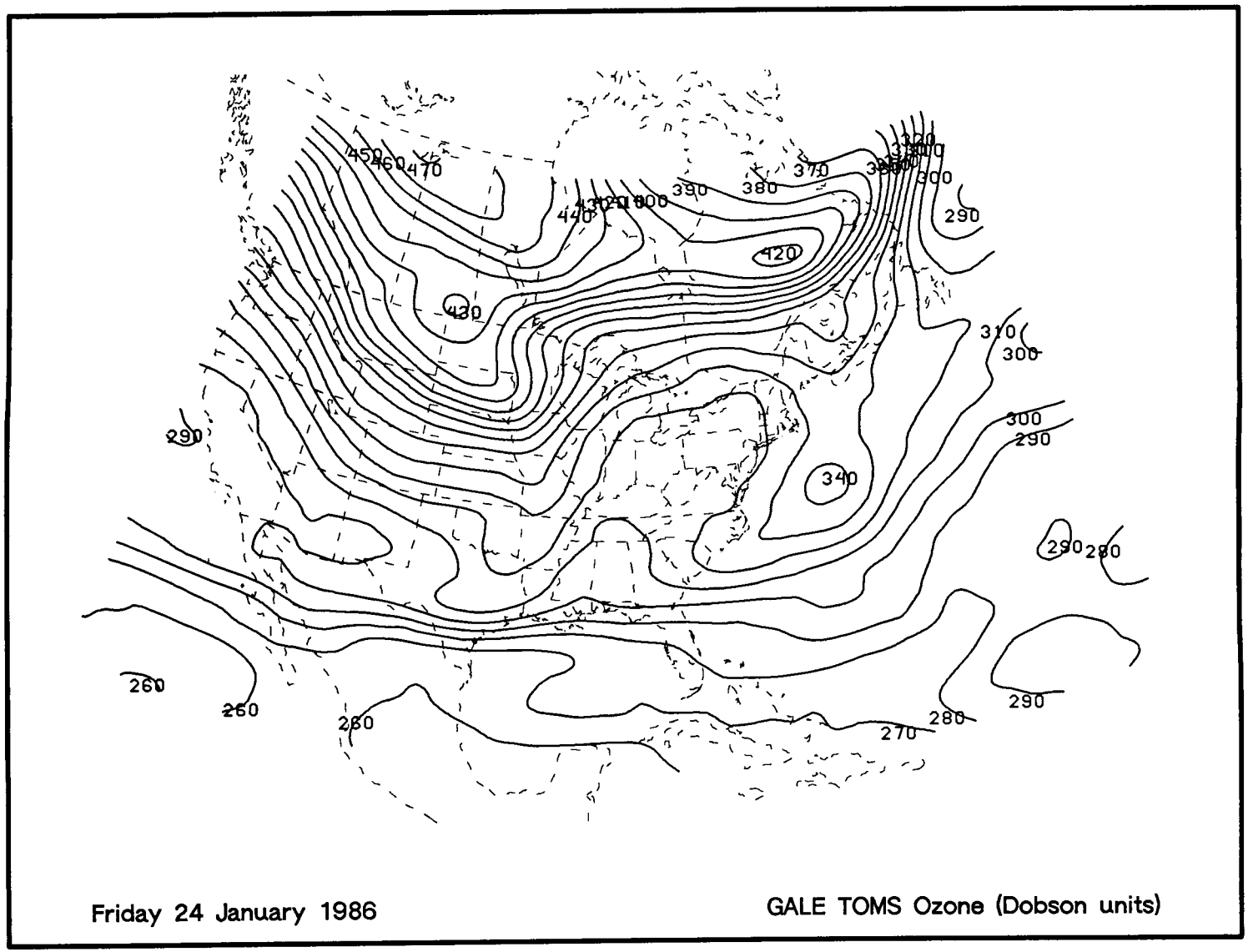

Figure 16. Ozone contour map (ten Dobson unit intervals) for GALE Day 10 Friday, 24 January 1986.

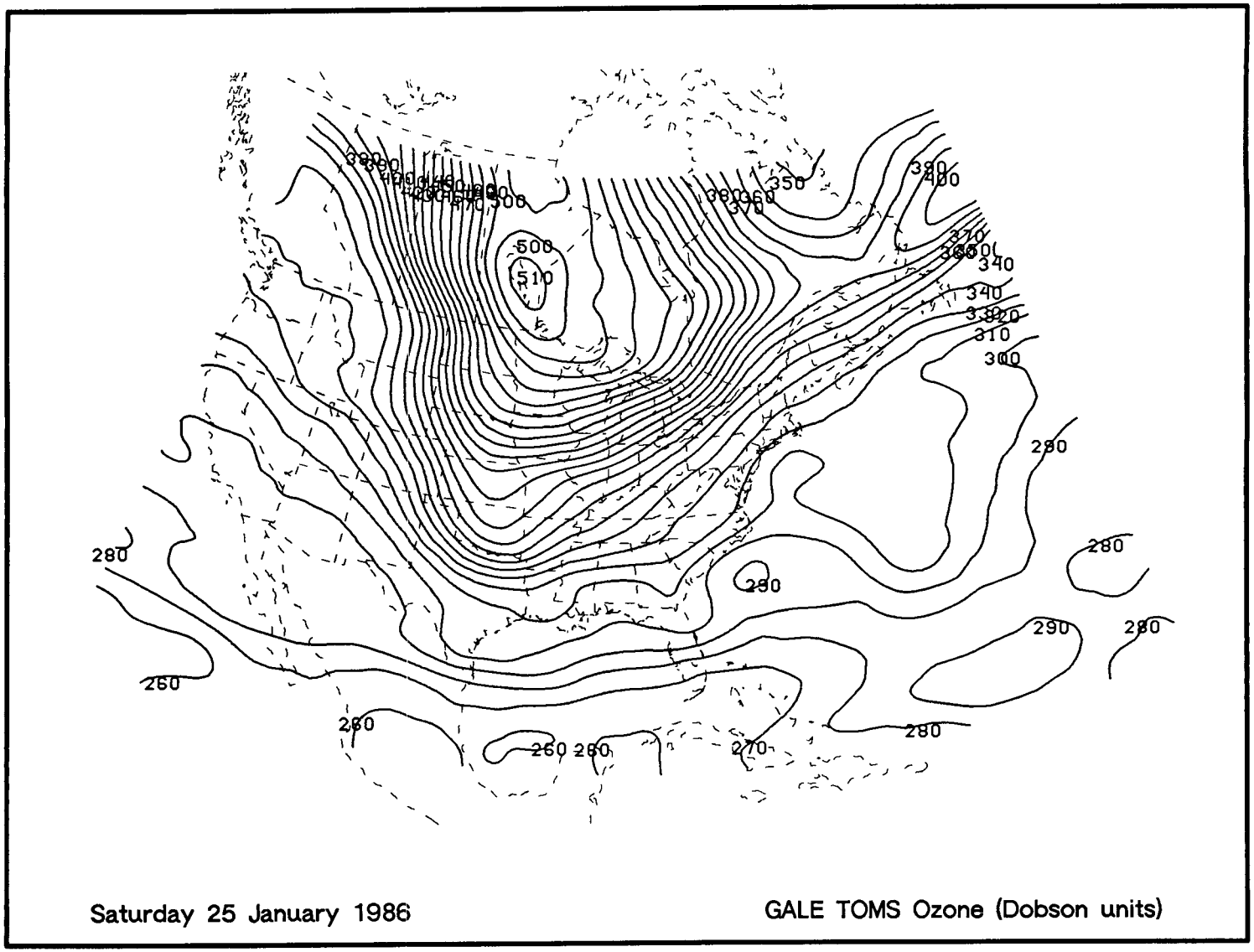

Figure 17. Ozone contour map (ten Dobson unit intervals) for GALE Day 11 Saturday, 25 January 1986.

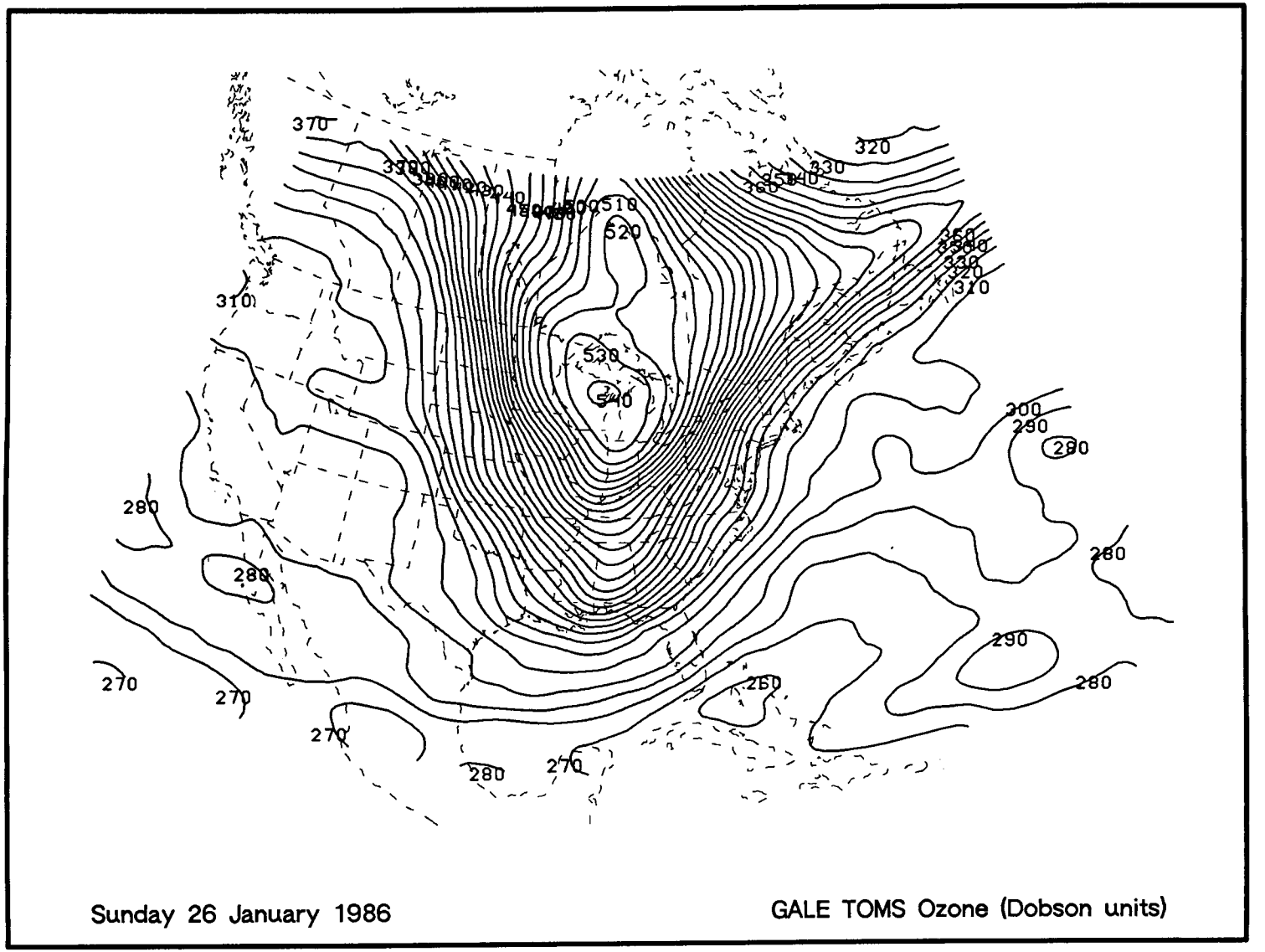

Figure 18. Ozone contour map (ten Dobson unit intervals) for GALE Day 12 Sunday, 26 January 1986.

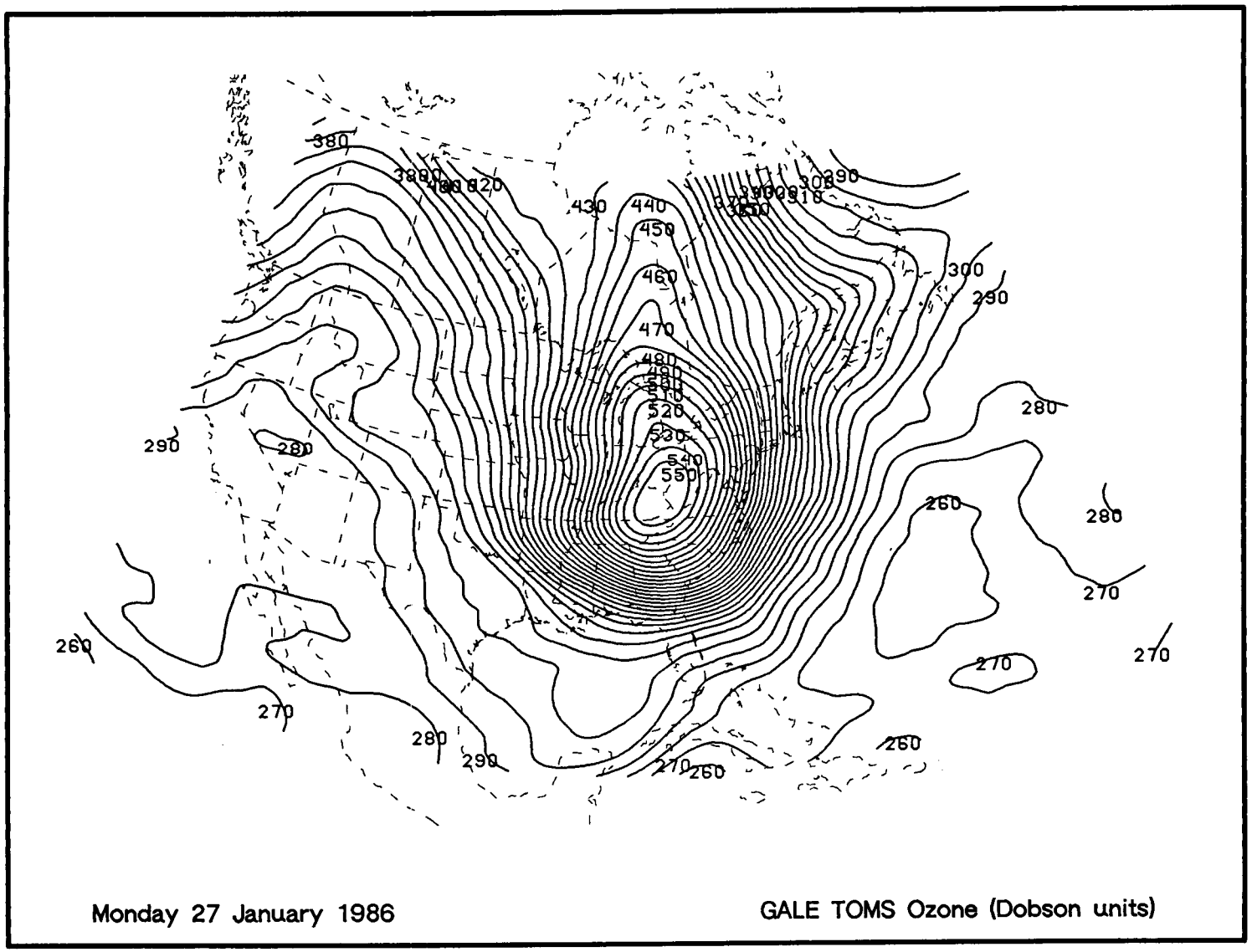

Figure 19. Ozone contour map (ten Dobson unit intervals) for GALE Day 13 Monday, 27 January 1986.

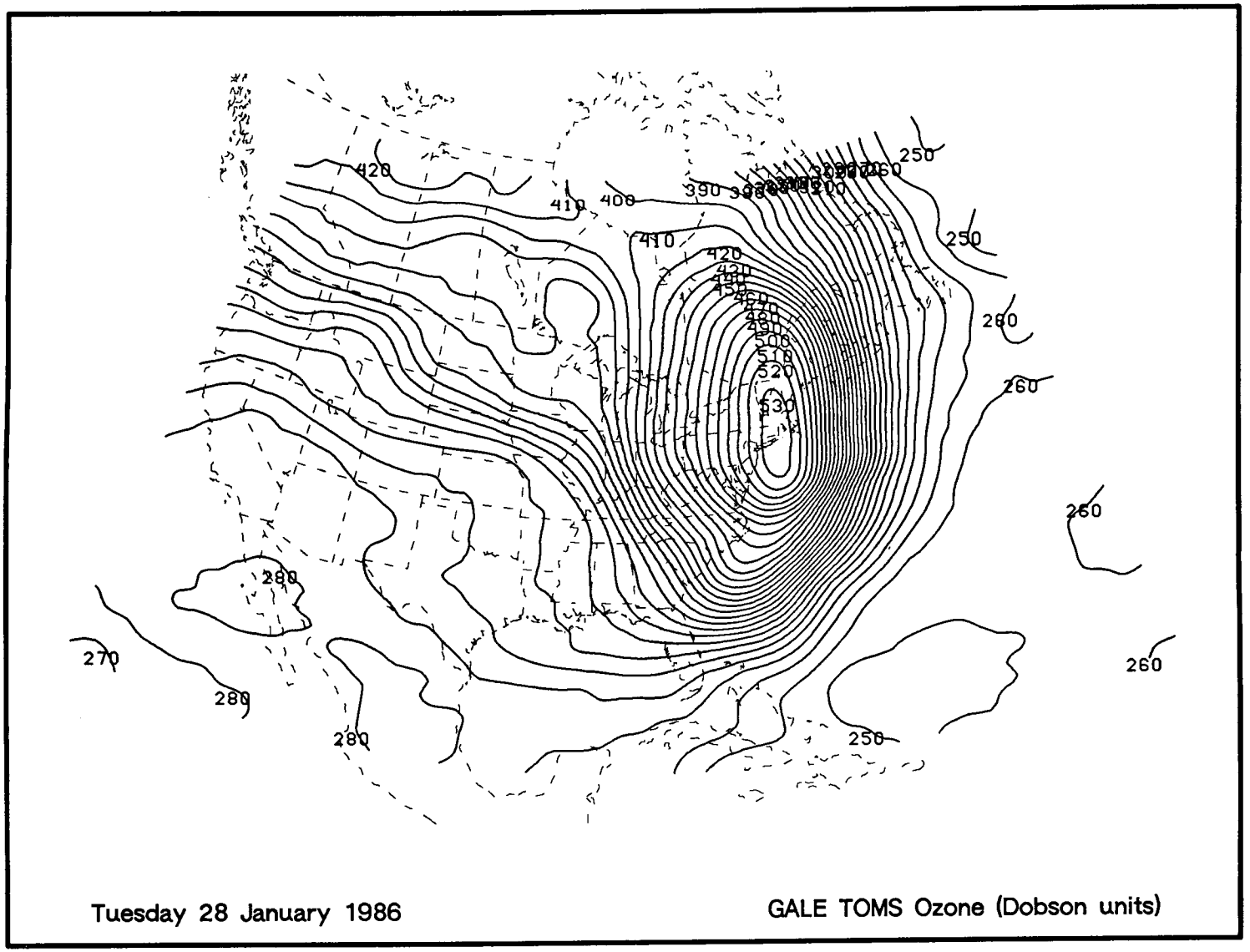

Figure 20. Ozone contour map (ten Dobson unit intervals) for GALE Day 14 Tuesday, 28 January 1986.

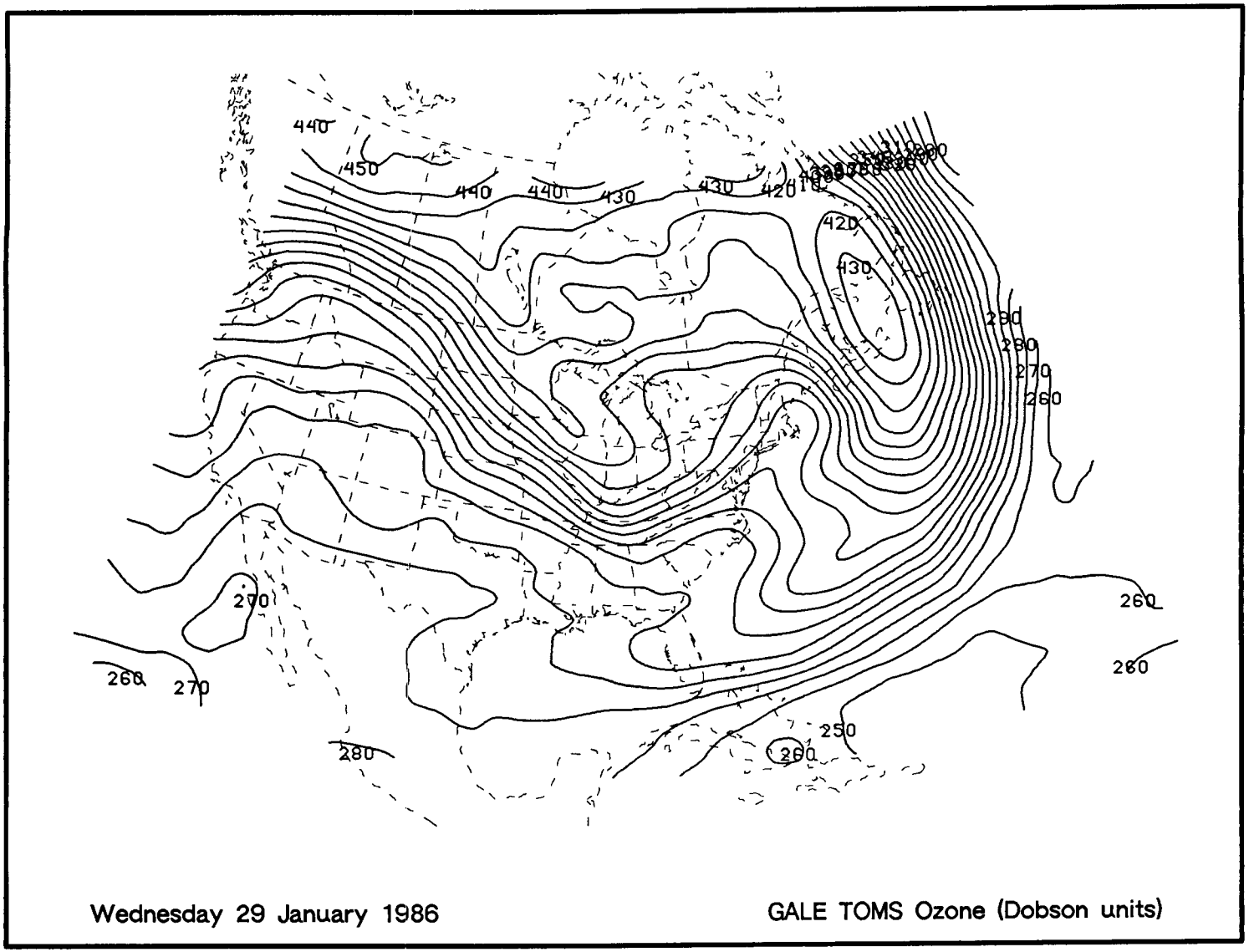

Figure 21. Ozone contour map (ten Dobson unit intervals) for GALE Day 15 Wednesday, 29 January 1986.

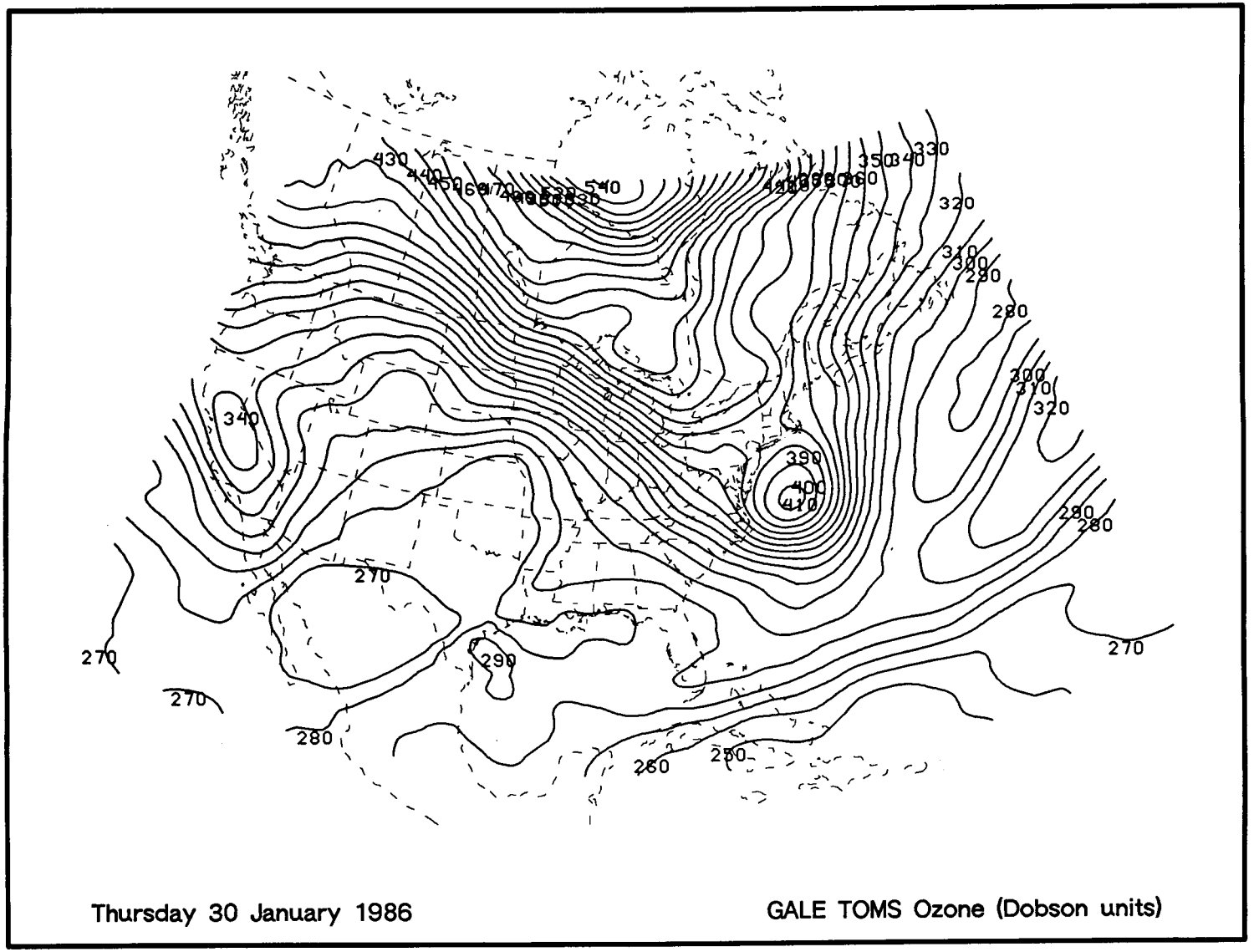

Figure 22. Ozone contour map (ten Dobson unit intervals) for GALE Day 16 Thursday, 30 January 1986.

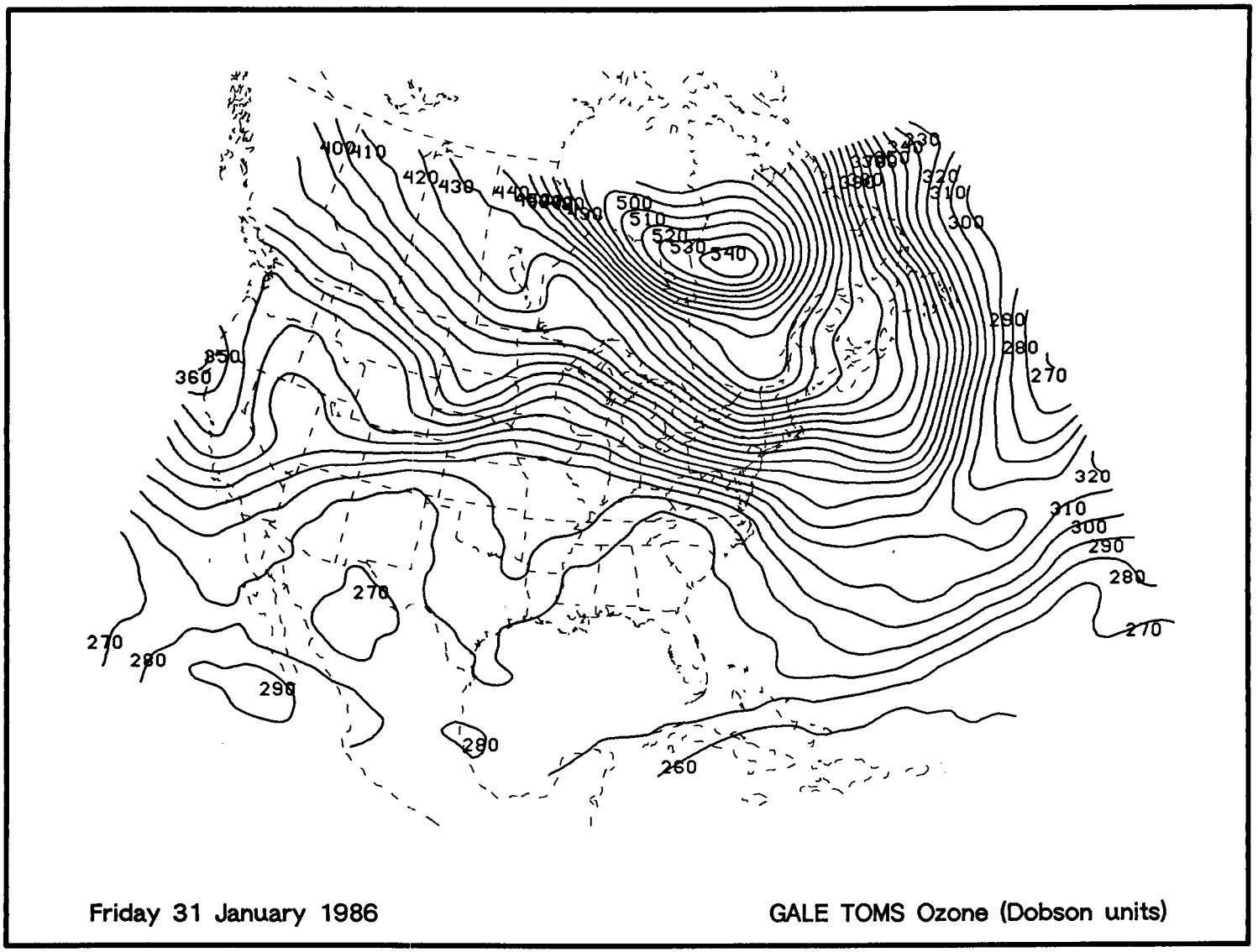

Figure 23. Ozone contour map (ten Dobson unit intervals) for GALE Day 17 Friday, 31 January 1986.

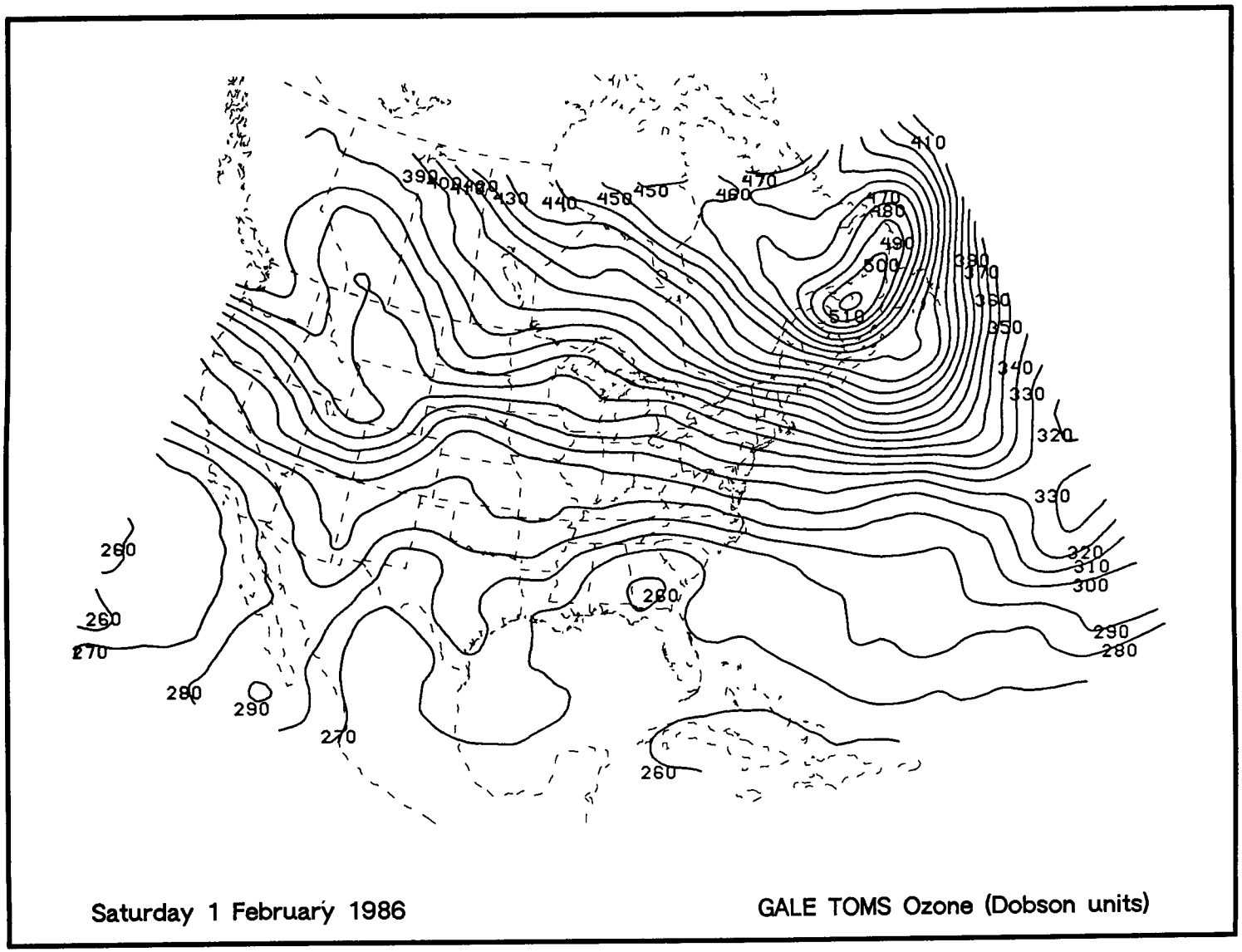

Figure 24. Ozone contour map (ten Dobson unit intervals) for GALE Day 18 Saturday, 1 February 1986.

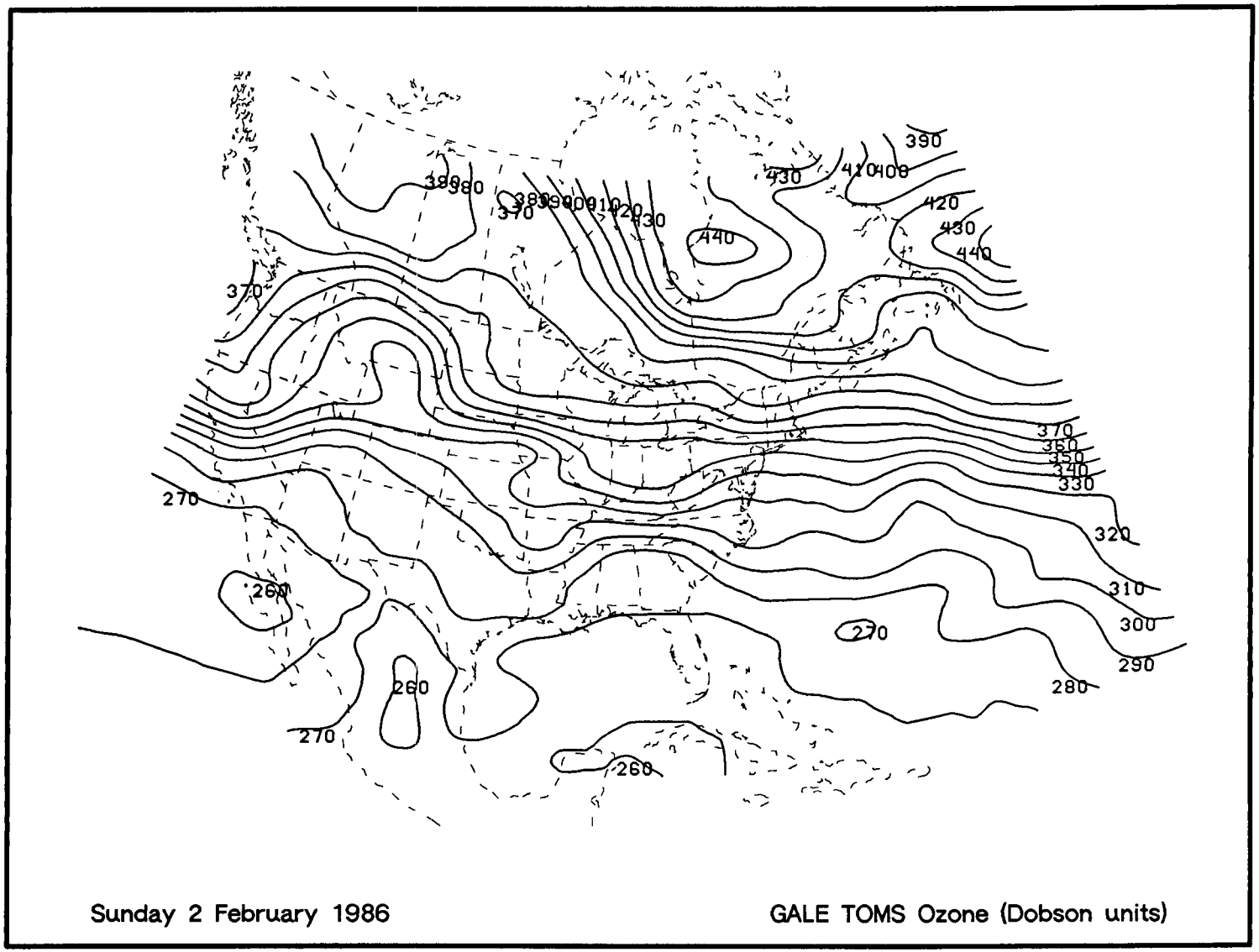

Figure 25. Ozone contour map (ten Dobson unit intervals) for GALE Day 19 Sunday, 2 February 1986.

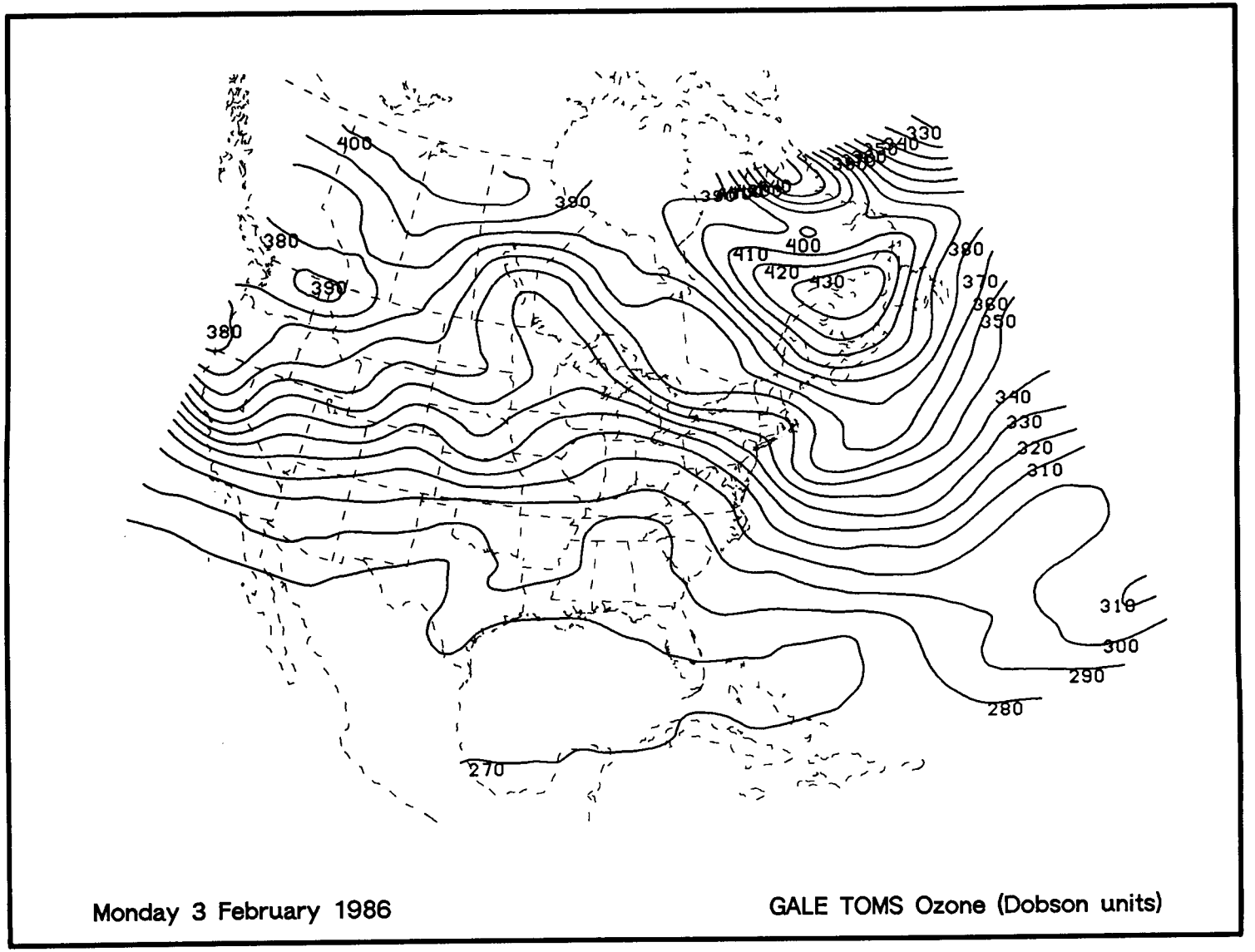

Figure 26. Ozone contour map (ten Dobson unit intervals) for GALE Day 20 Monday, 3 February 1986.

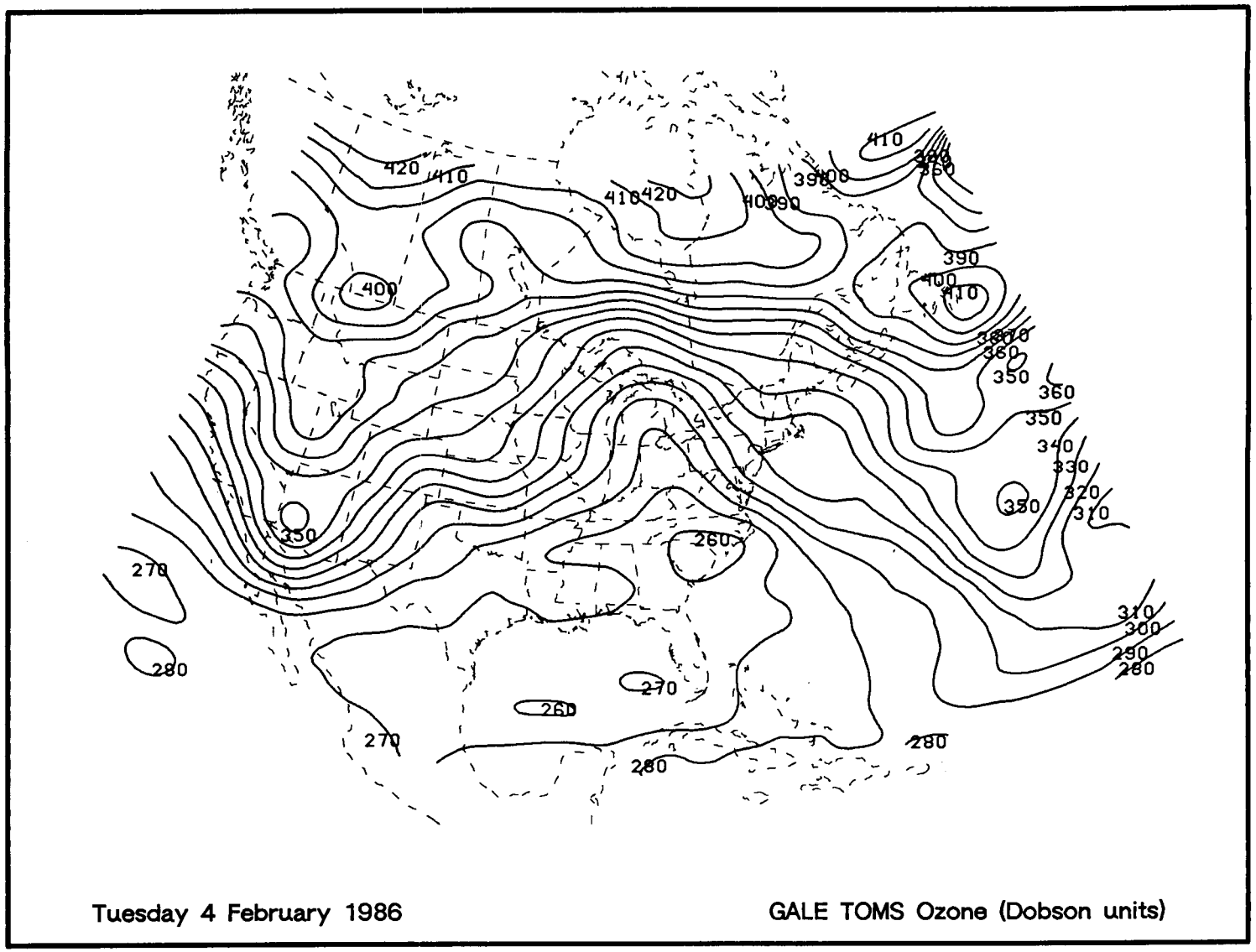

Figure 27. Ozone contour map (ten Dobson unit intervals) for GALE Day 21 Tuesday, 4 February 1986.

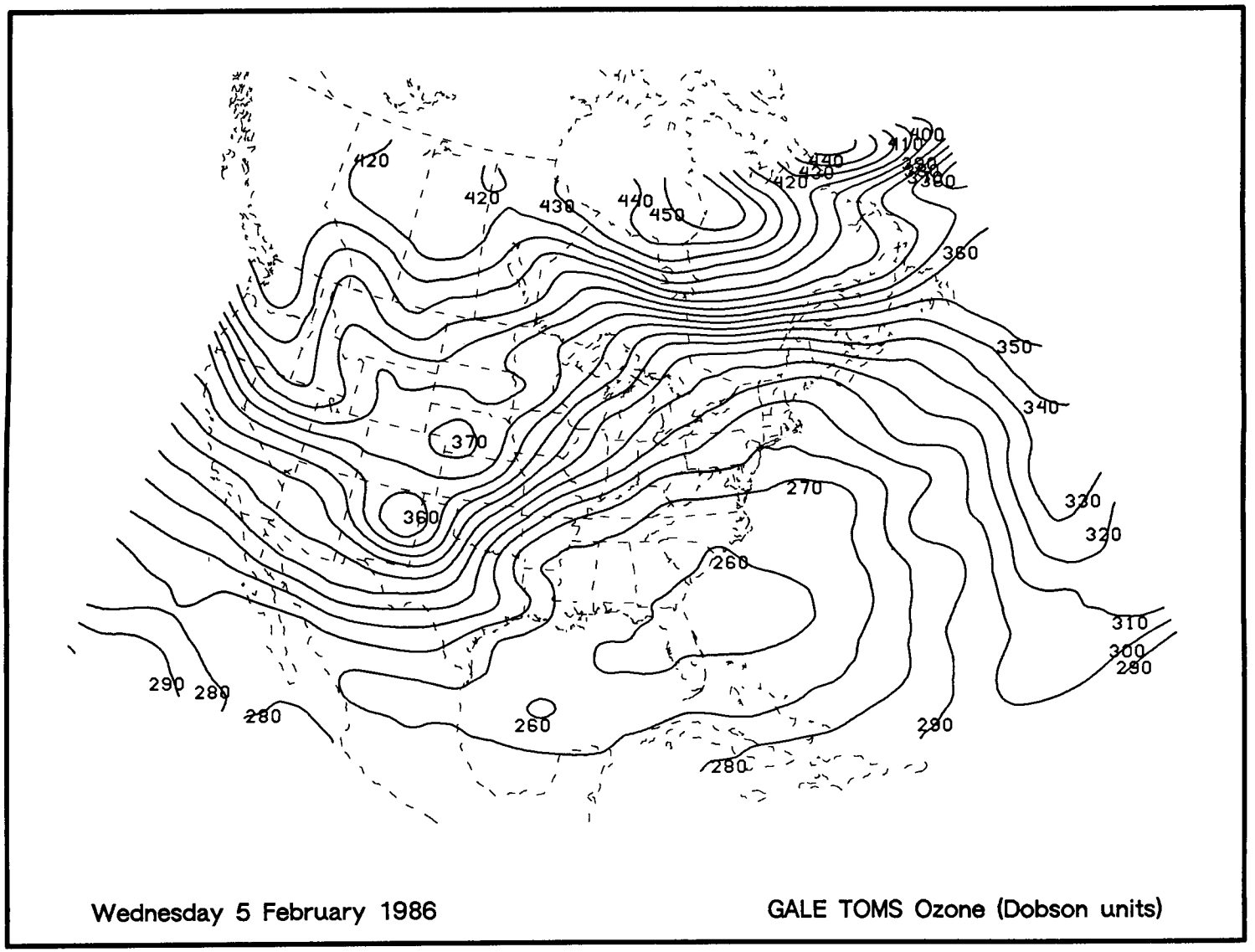

Figure 28. Ozone contour map (ten Dobson unit intervals) for GALE Day 22 Wednesday, 5 February 1986.

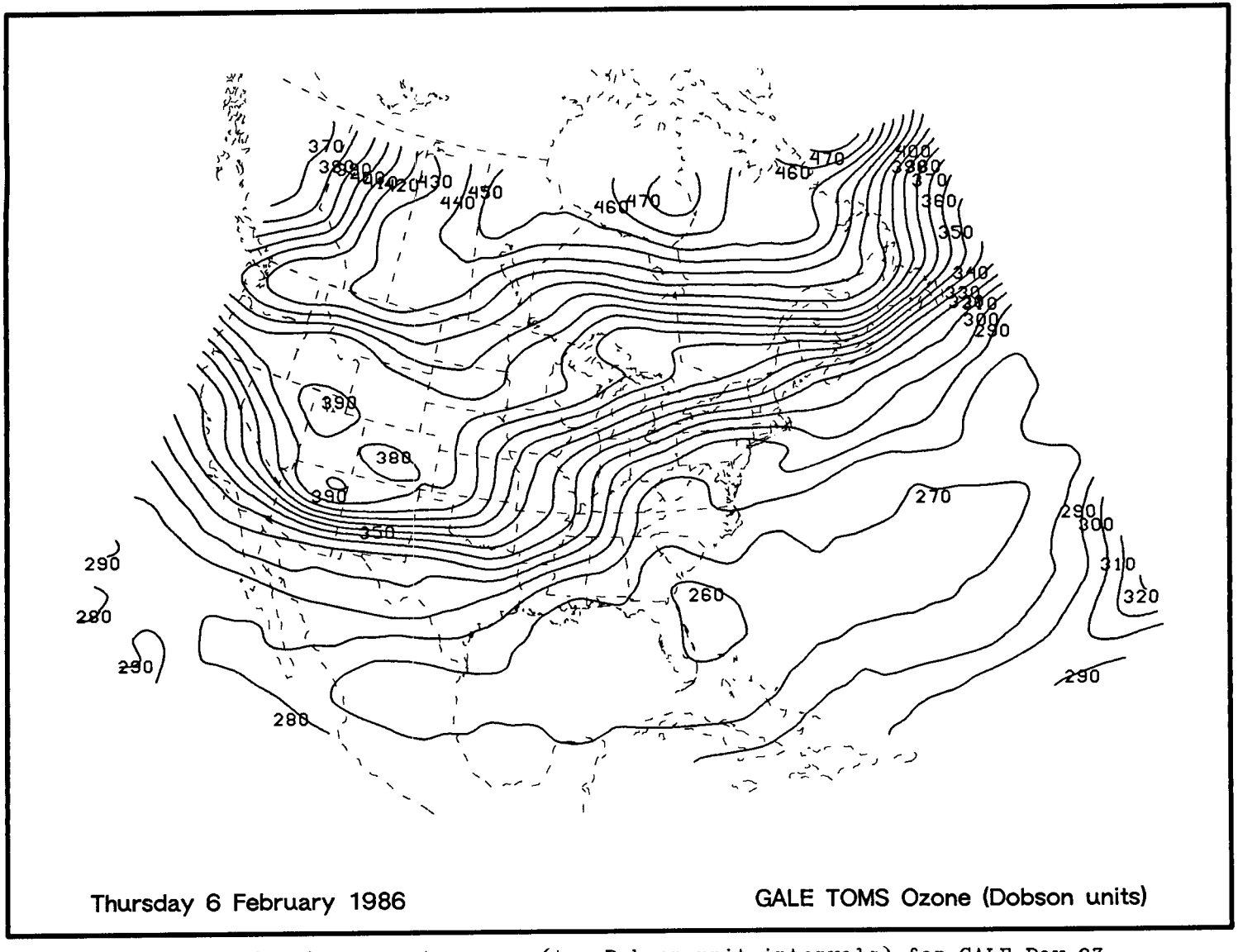

Figure 29. Ozone contour map (ten Dobson unit intervals) for GALE Day 23 Thursday, 6 February 1986.

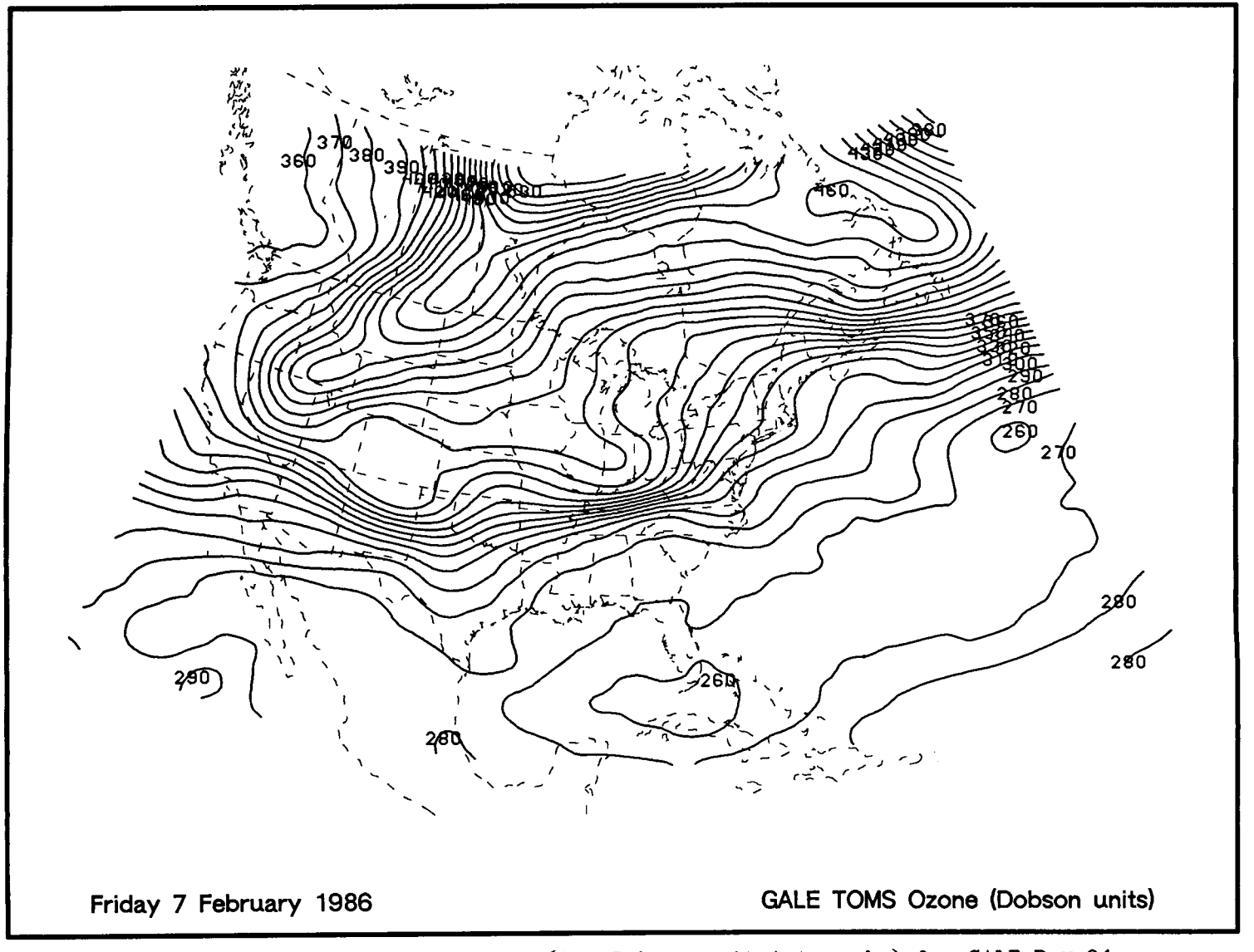

Figure 30. Ozone contour map (ten Dobson unit intervals) for GALE Day 24 Friday, 7 February 1986.

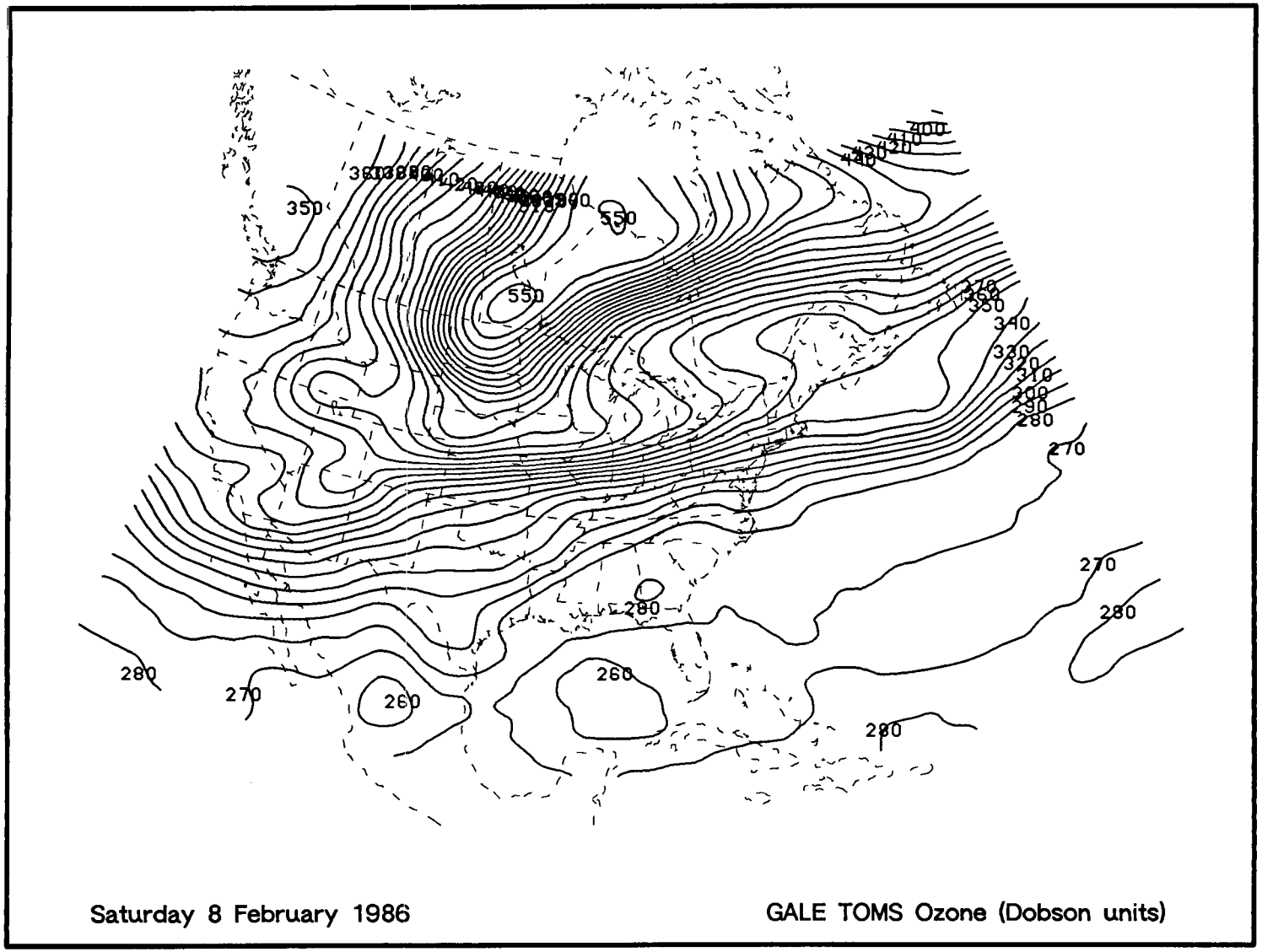

Figure 31. Ozone contour map (ten Dobson unit intervals) for GALE Day 25 Saturday, 8 February 1986.

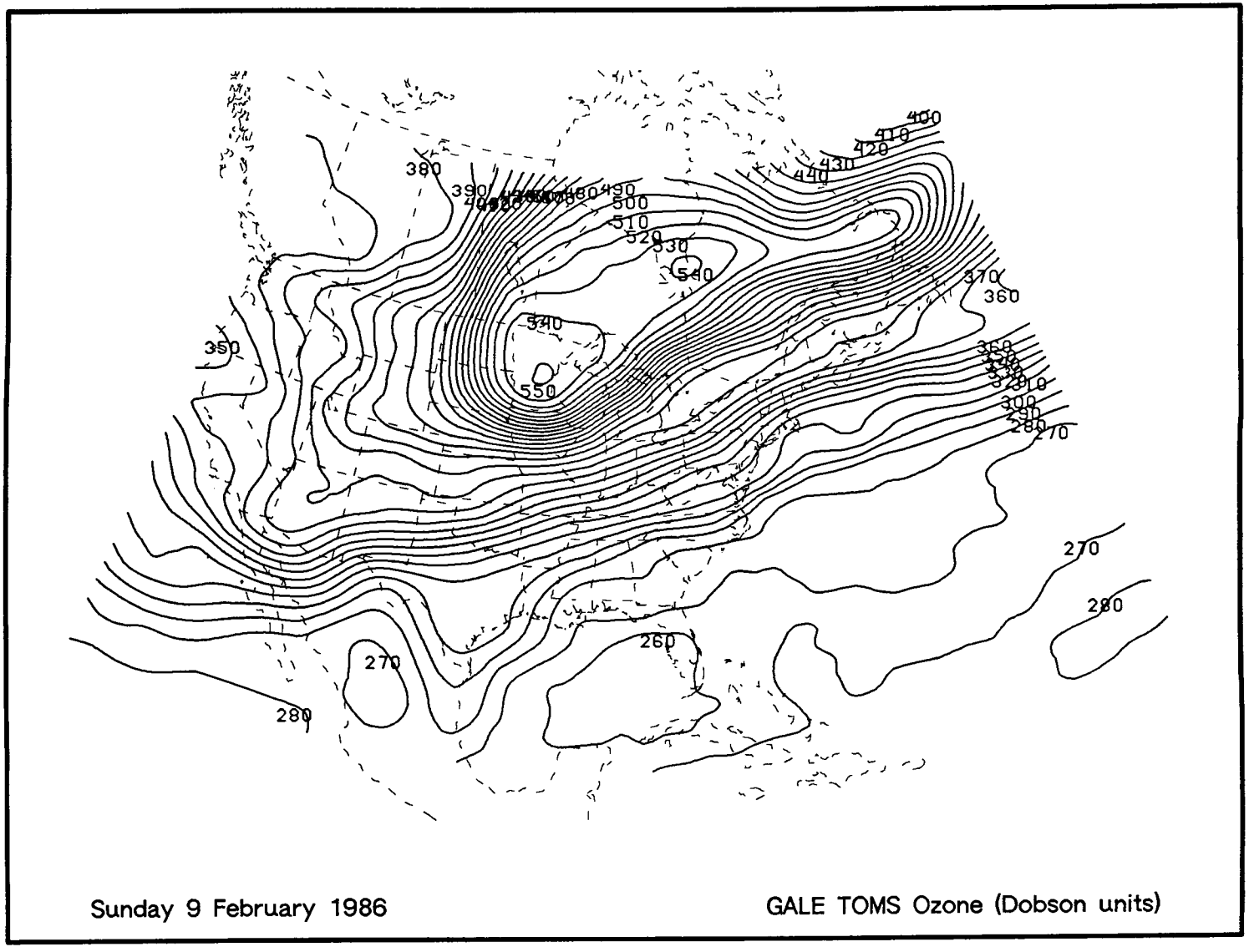

Figure 32. Ozone contour map (ten Dobson unit intervals) for GALE Day 26 Sunday, 9 February 1986.

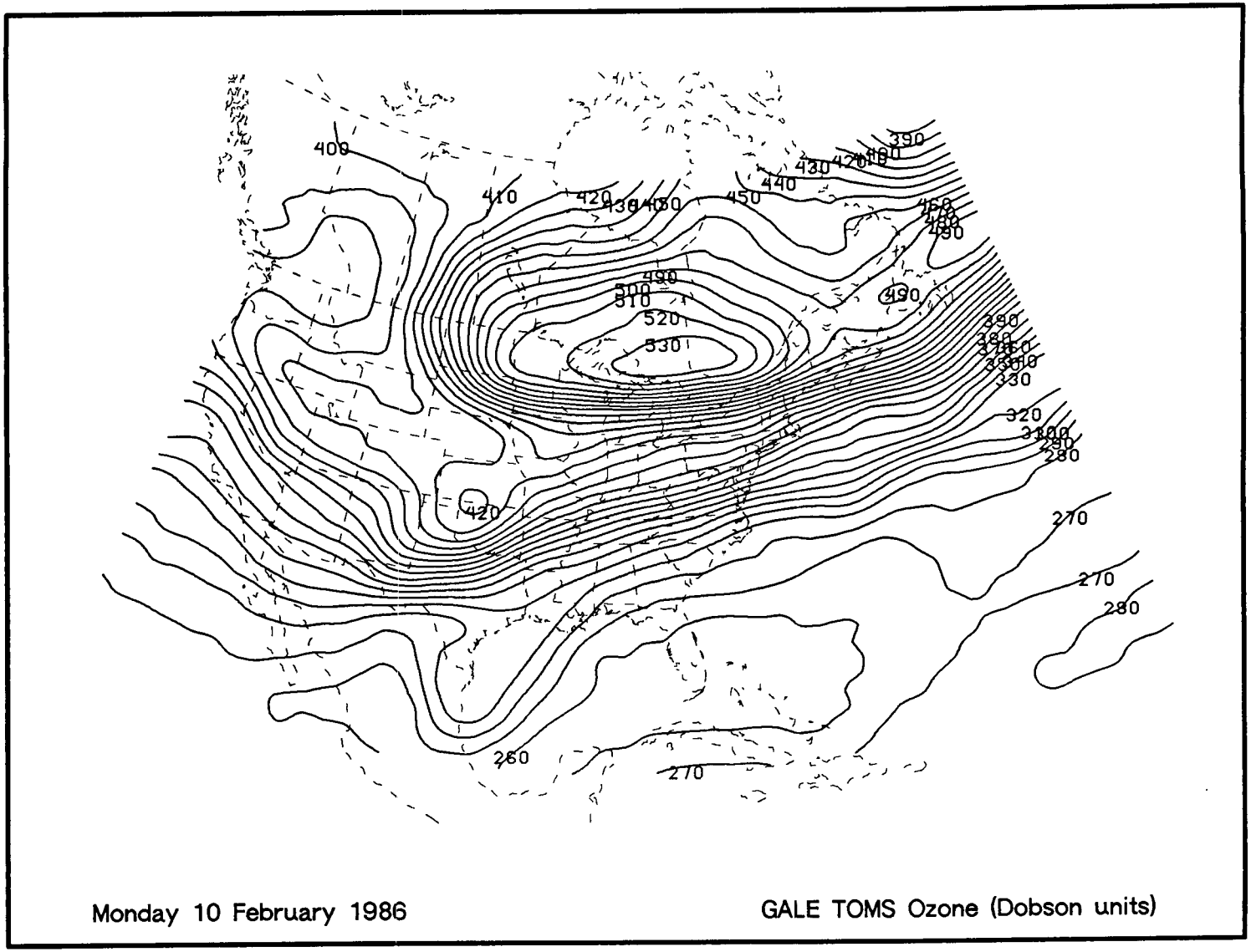

Figure 33. Ozone contour map (ten Dobson unit intervals) for GALE Day 27 Monday, 10 February 1986.

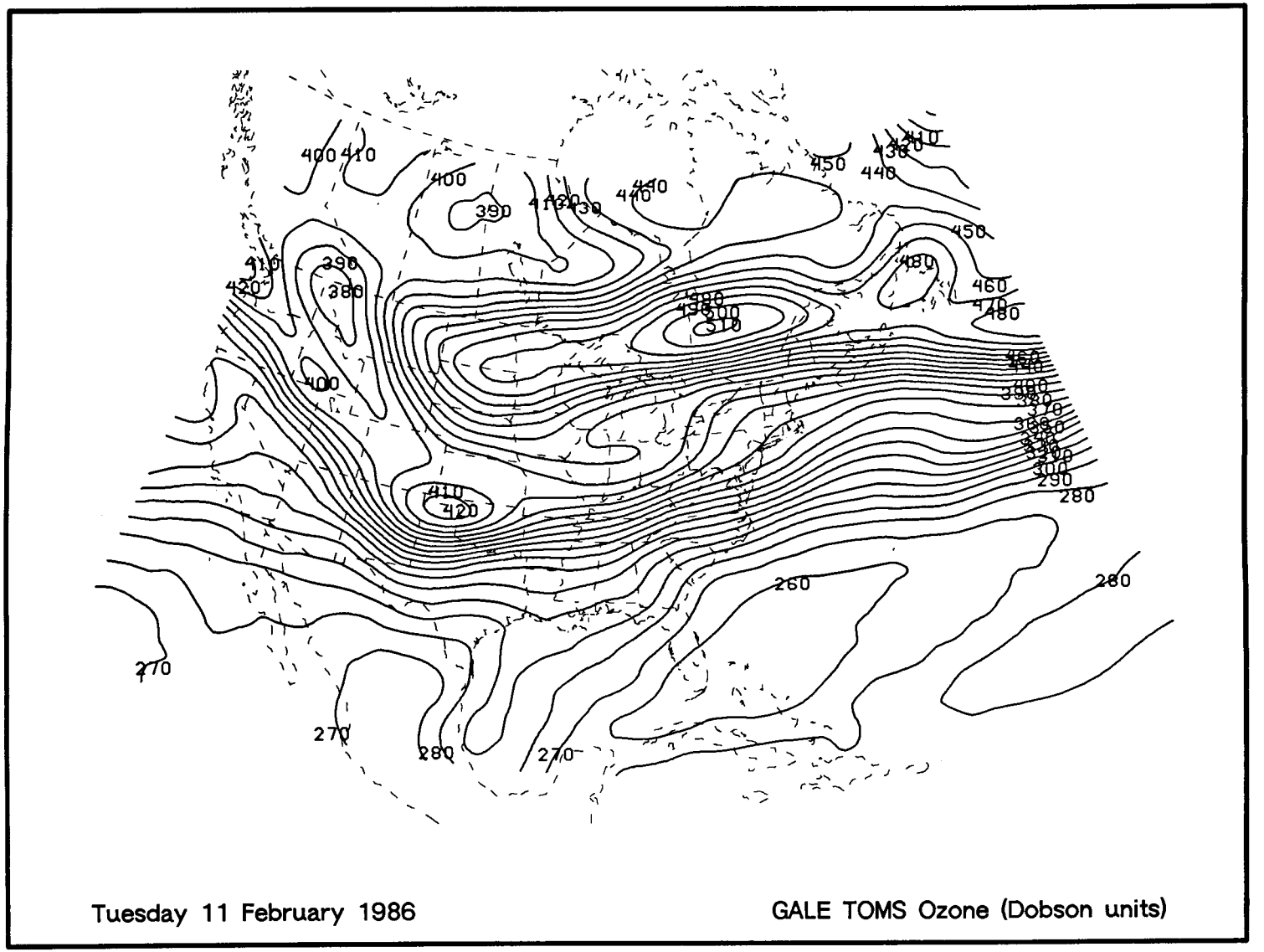

Figure 34. Ozone contour map (ten Dobson unit intervals) for GALE Day 28 Tuesday, 11 February 1986.

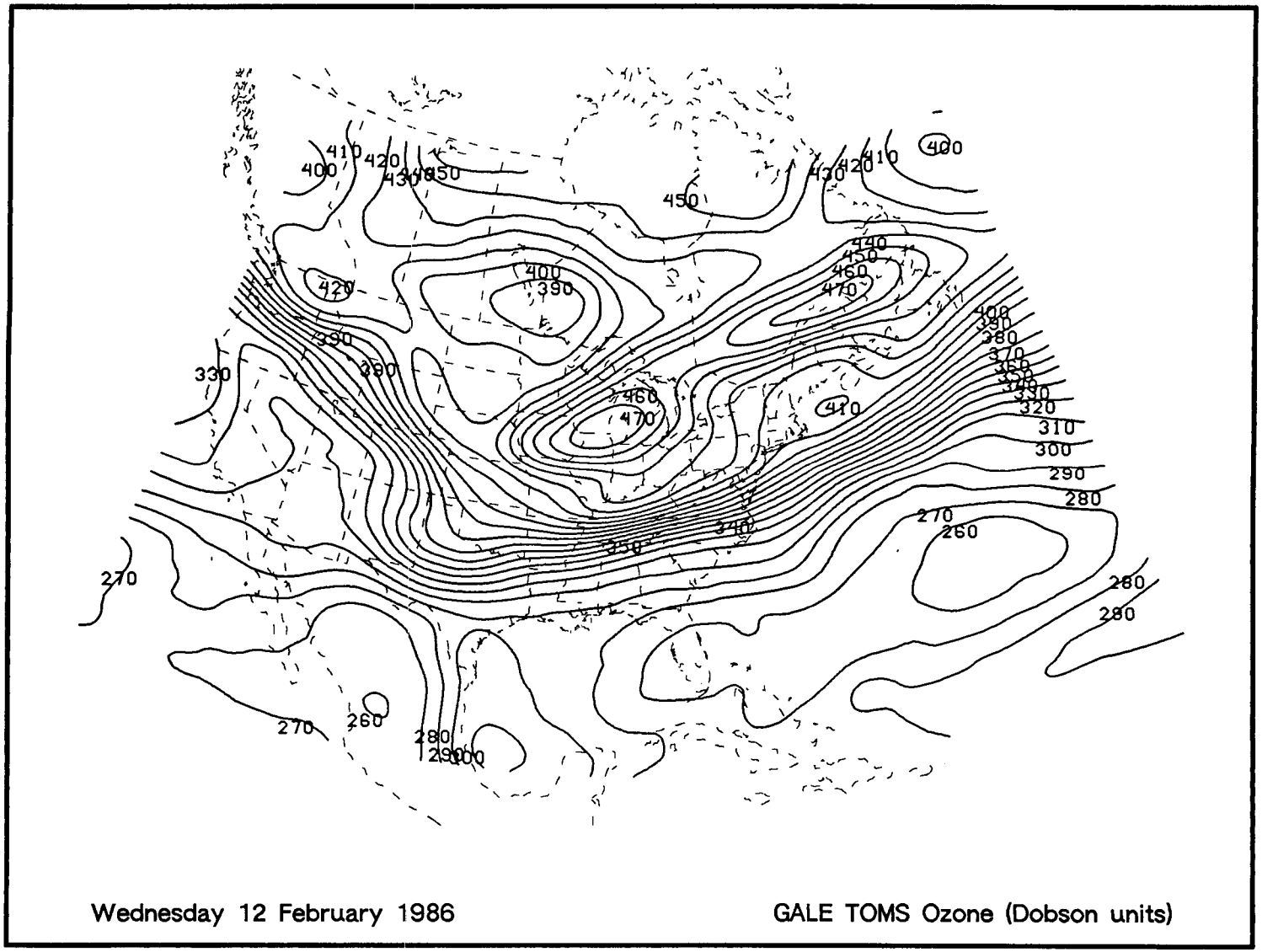

Figure 35. Ozone contour map (ten Dobson unit intervals) for GALE Day 29 Wednesday, 12 February 1986.

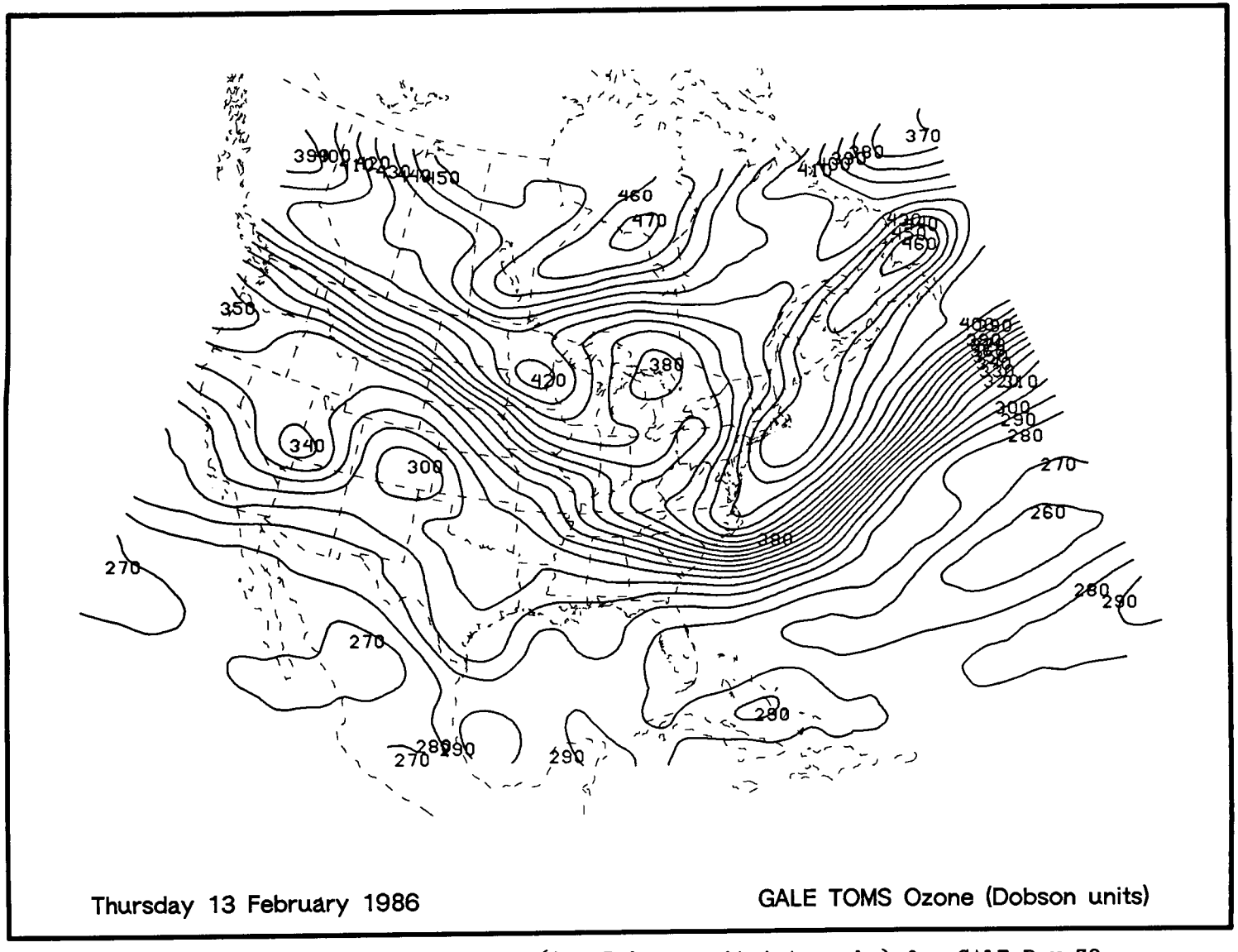

Figure 36. Ozone contour map (ten Dobson unit intervals) for GALE Day 30 Thursday, 13 February 1986.

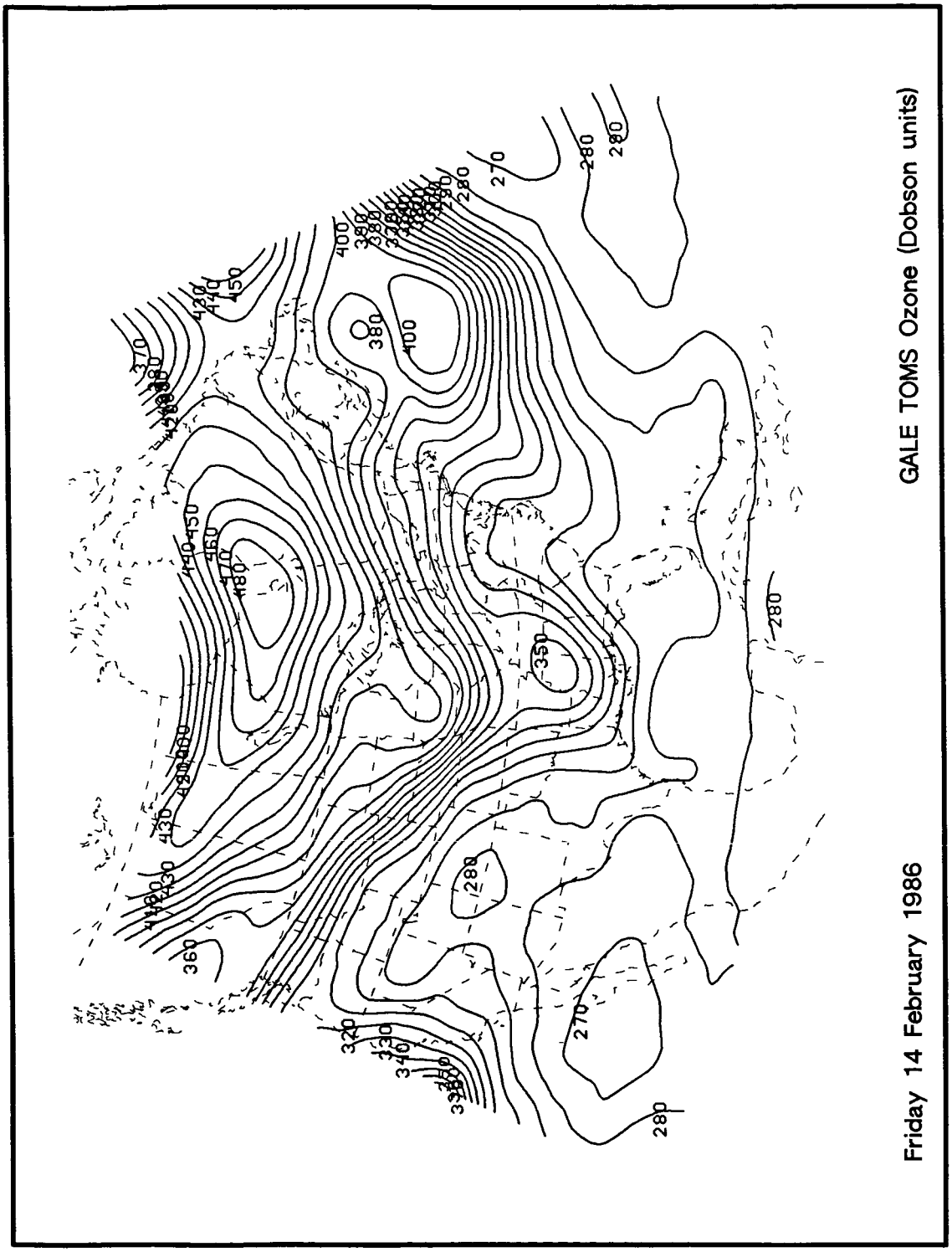

Figure 37. Ozone contour map (ten Dobson unit intervals) for GALE Day 31
Friday, 14 February 1986.

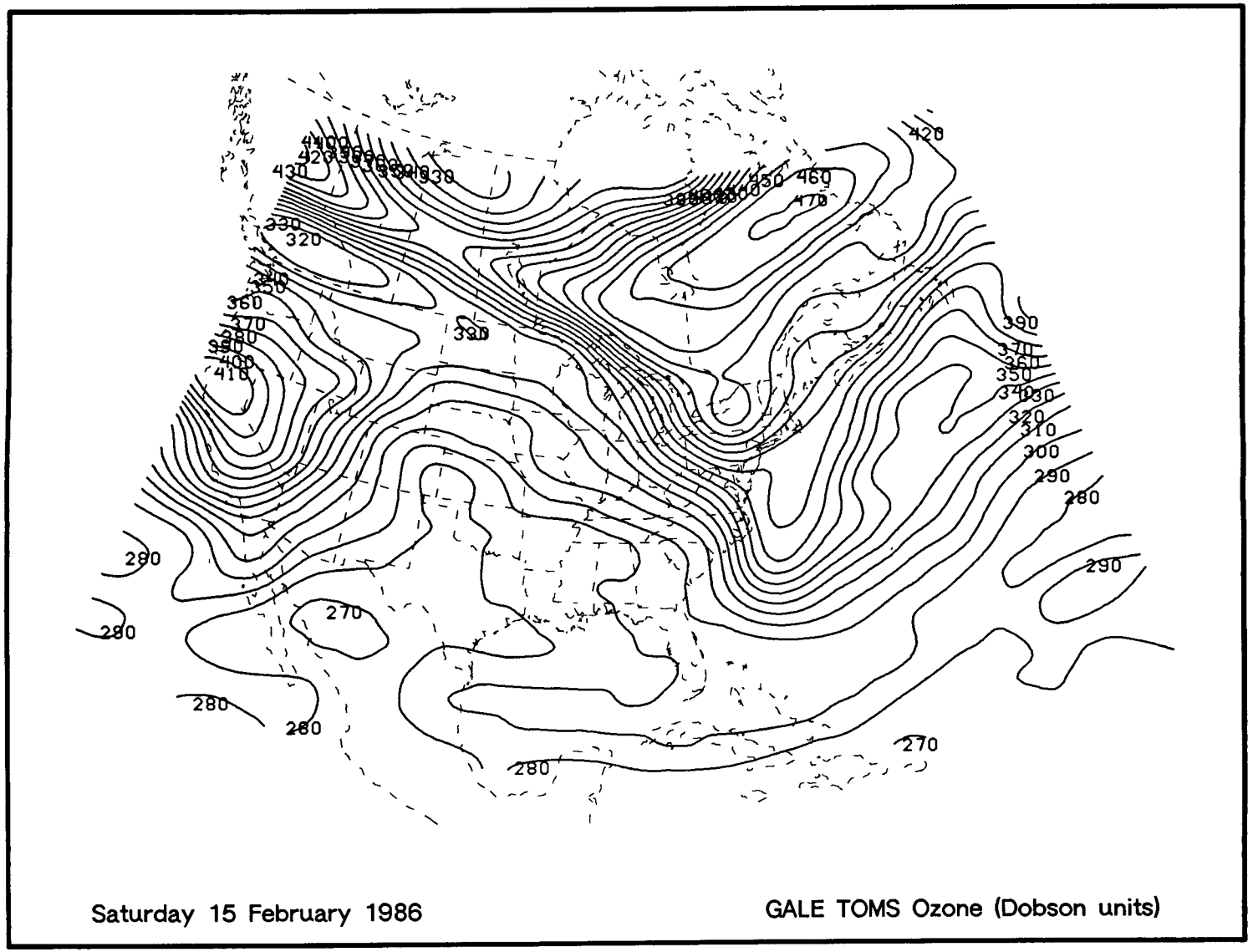

Figure 38. Ozone contour map (ten Dobson unit intervals) for GALE Day 32 Saturday, 15 February 1986.

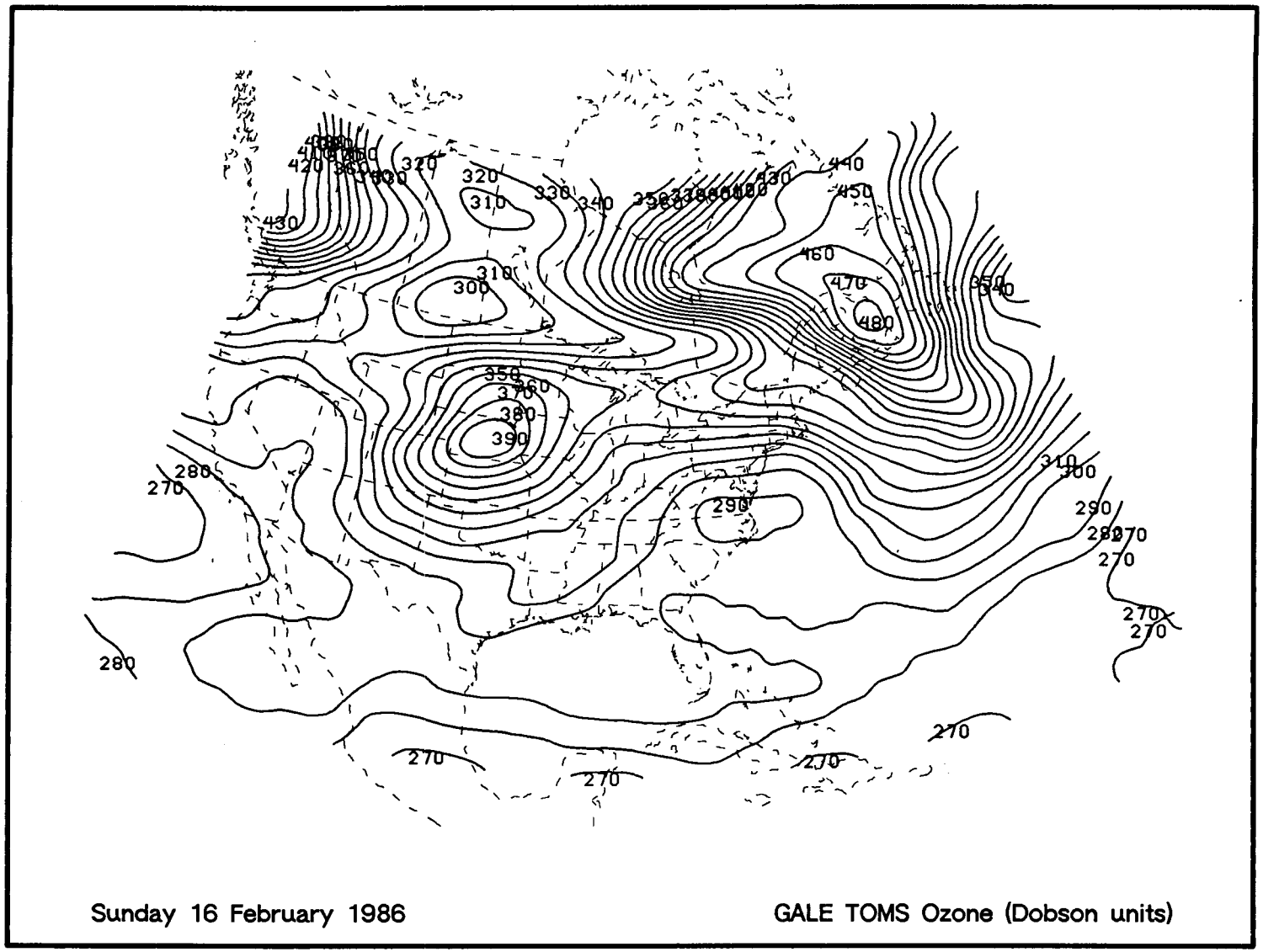

Figure 39. Ozone contour map (ten Dobson unit intervals) for GALE Day 33 Sunday, 16 February 1986.

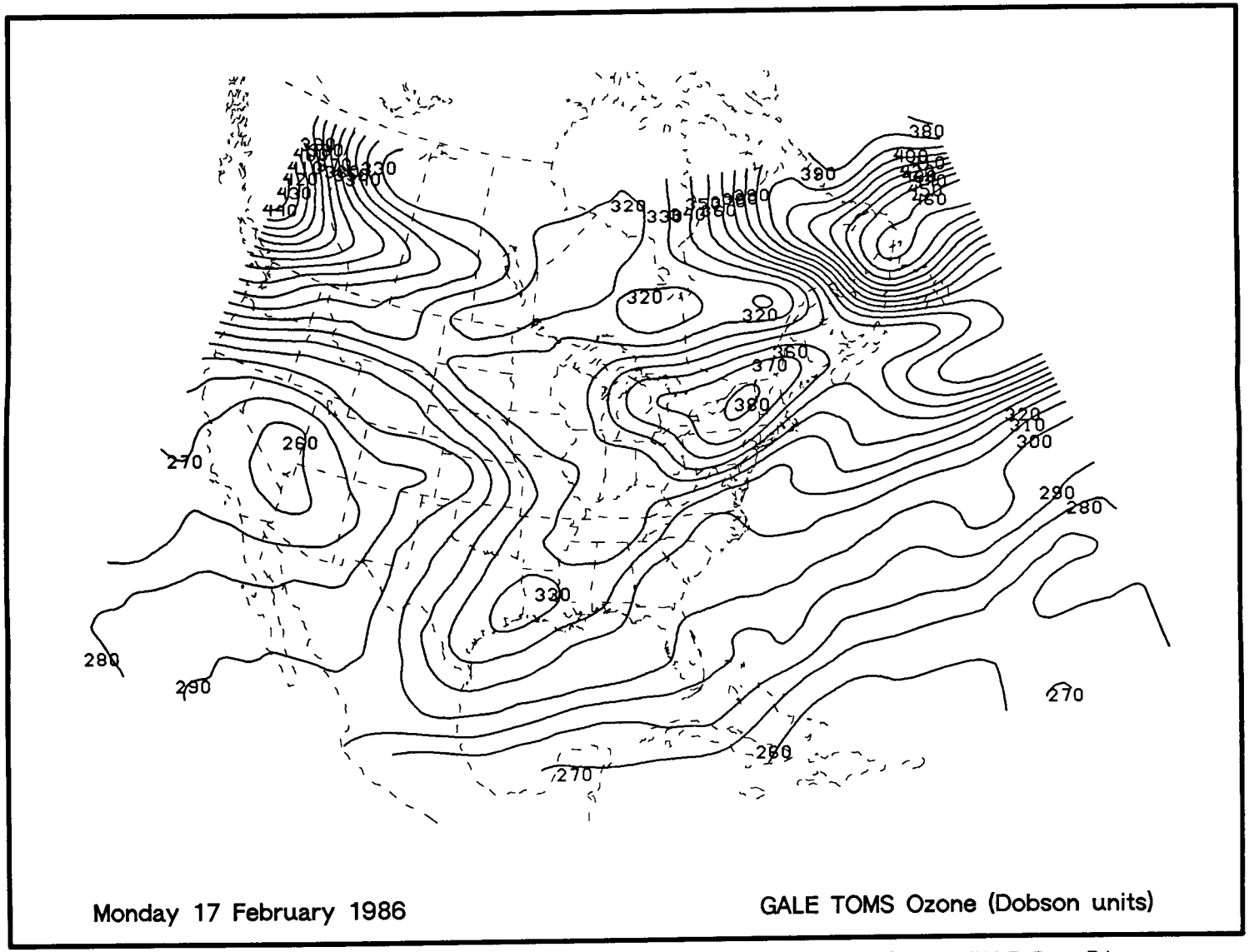

Figure 40. Ozone contour map (ten Dobson unit intervals) for GALE Day 34 Monday, 17 February 1986.

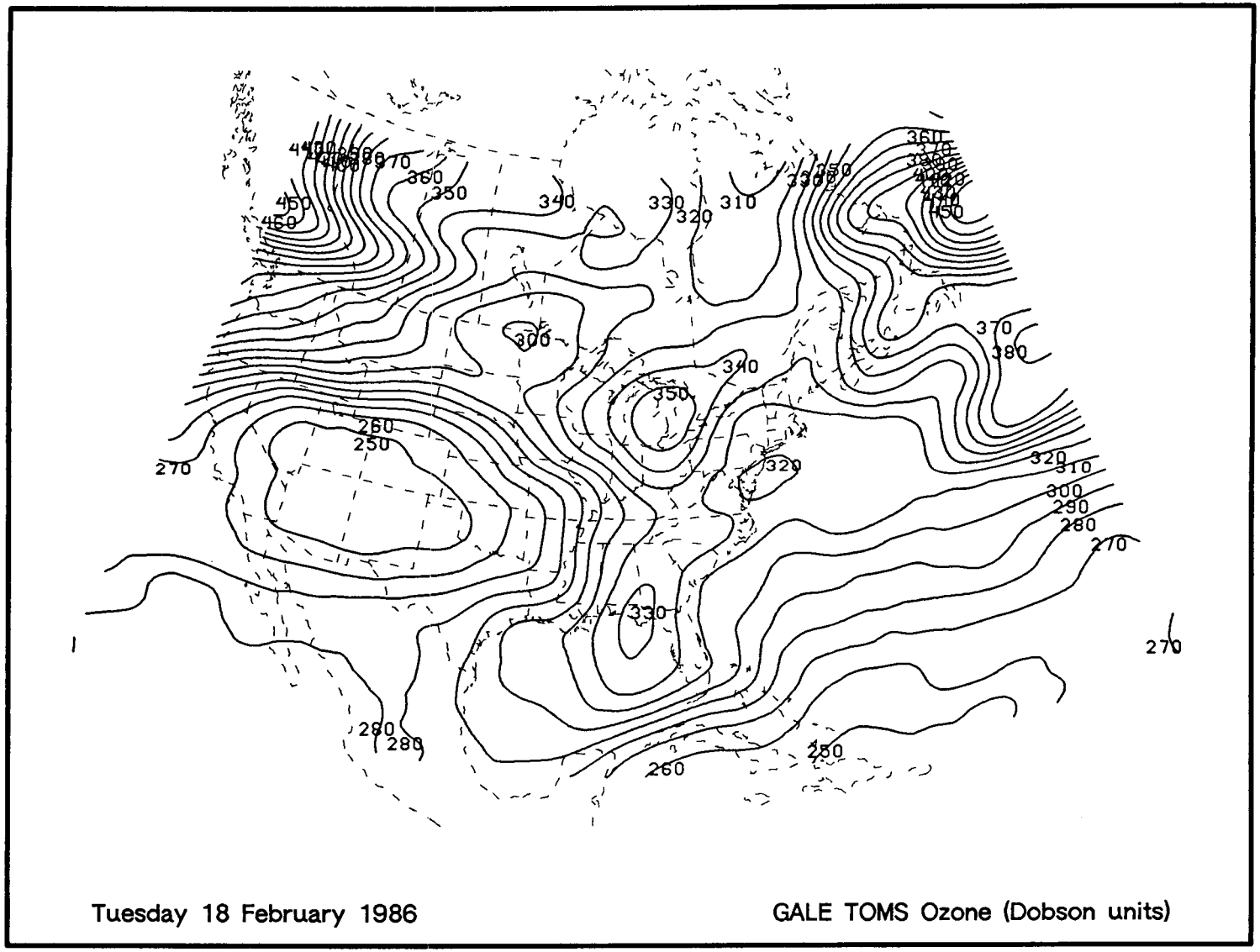

Figure 41. Ozone contour map (ten Dobson unit intervals) for GALE Day 35 Tuesday, 18 February 1986.

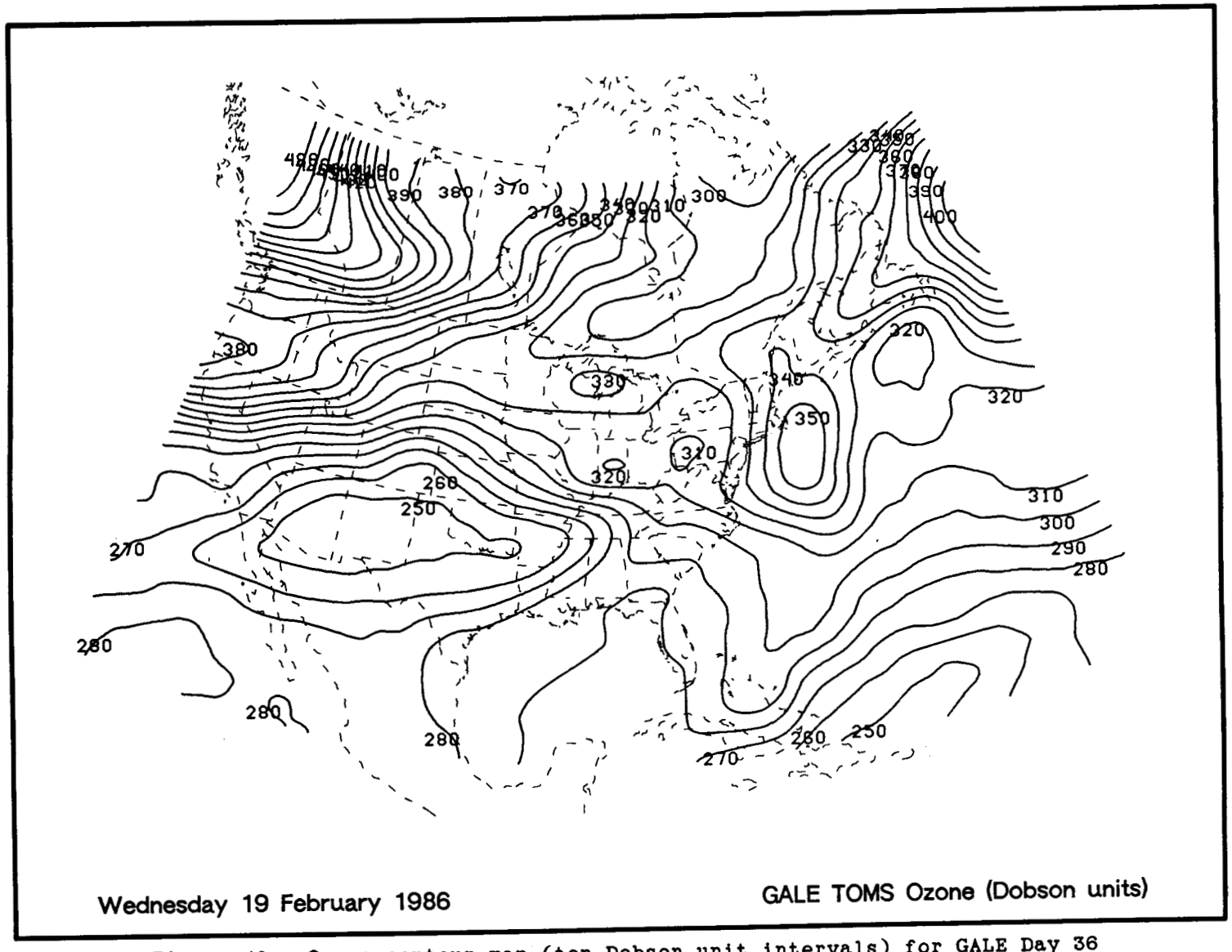

Figure 42. Ozone contour map (ten Dobson unit intervals) for GALE Day 36 Wednesday, 19 February 1986.

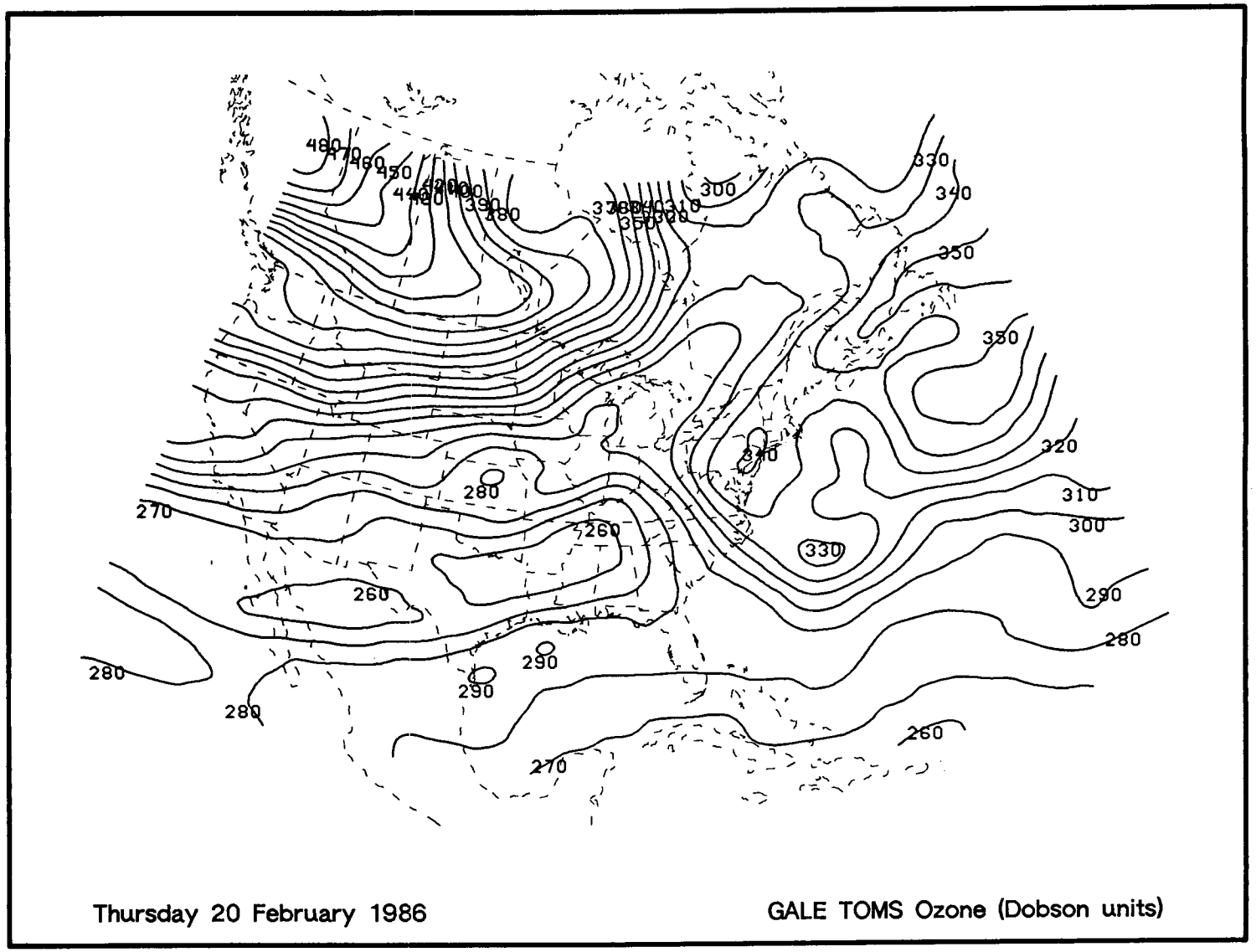

Figure 43. Ozone contour map (ten Dobson unit intervals) for GALE Day 37 Thursday, 20 February 1986.

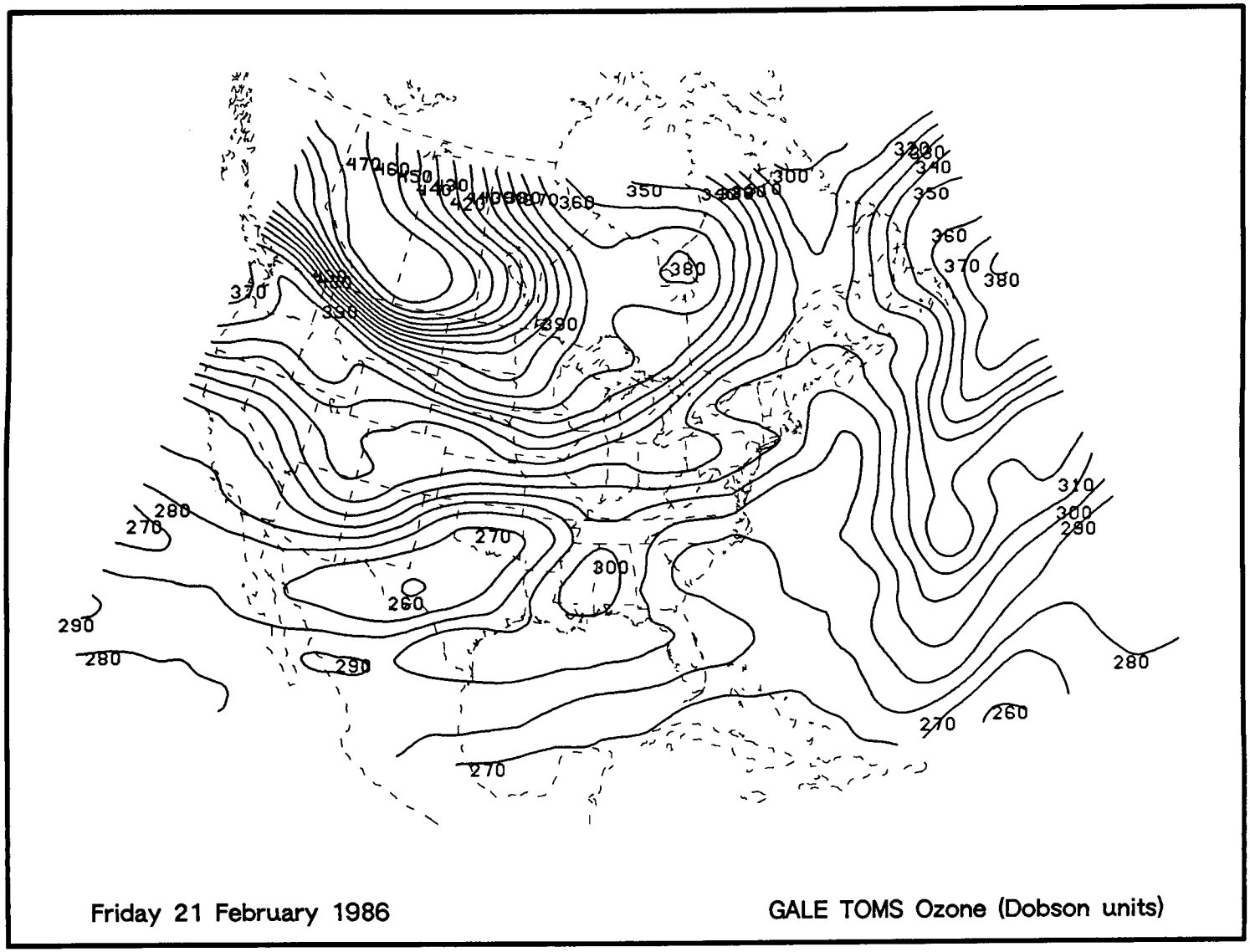

Figure 44. Ozone contour map (ten Dobson unit intervals) for GALE Day 38 Friday, 21 February 1986.

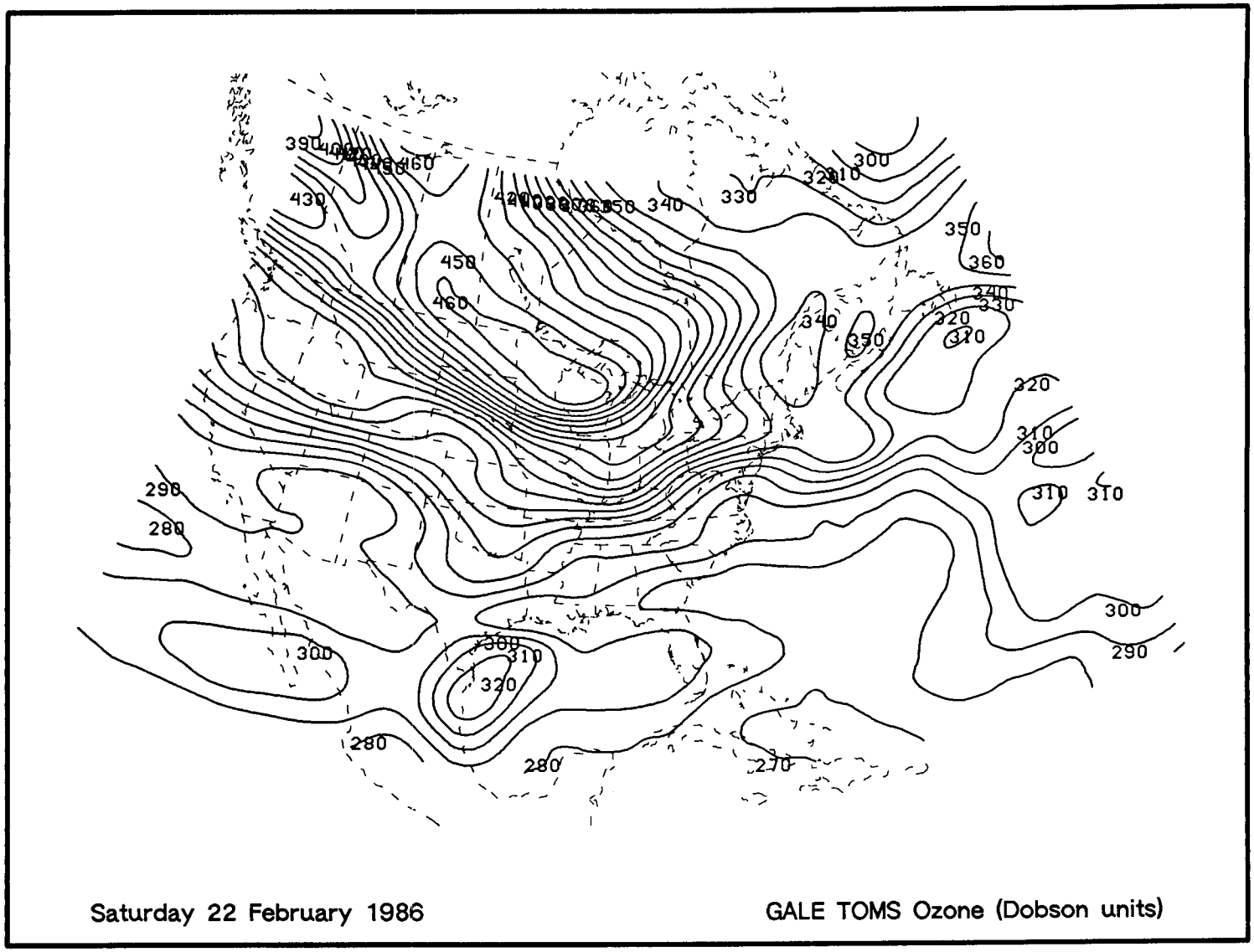

Figure 45. Ozone contour map (ten Dobson unit intervals) for GALE Day 39 Saturday, 22 February 1986.

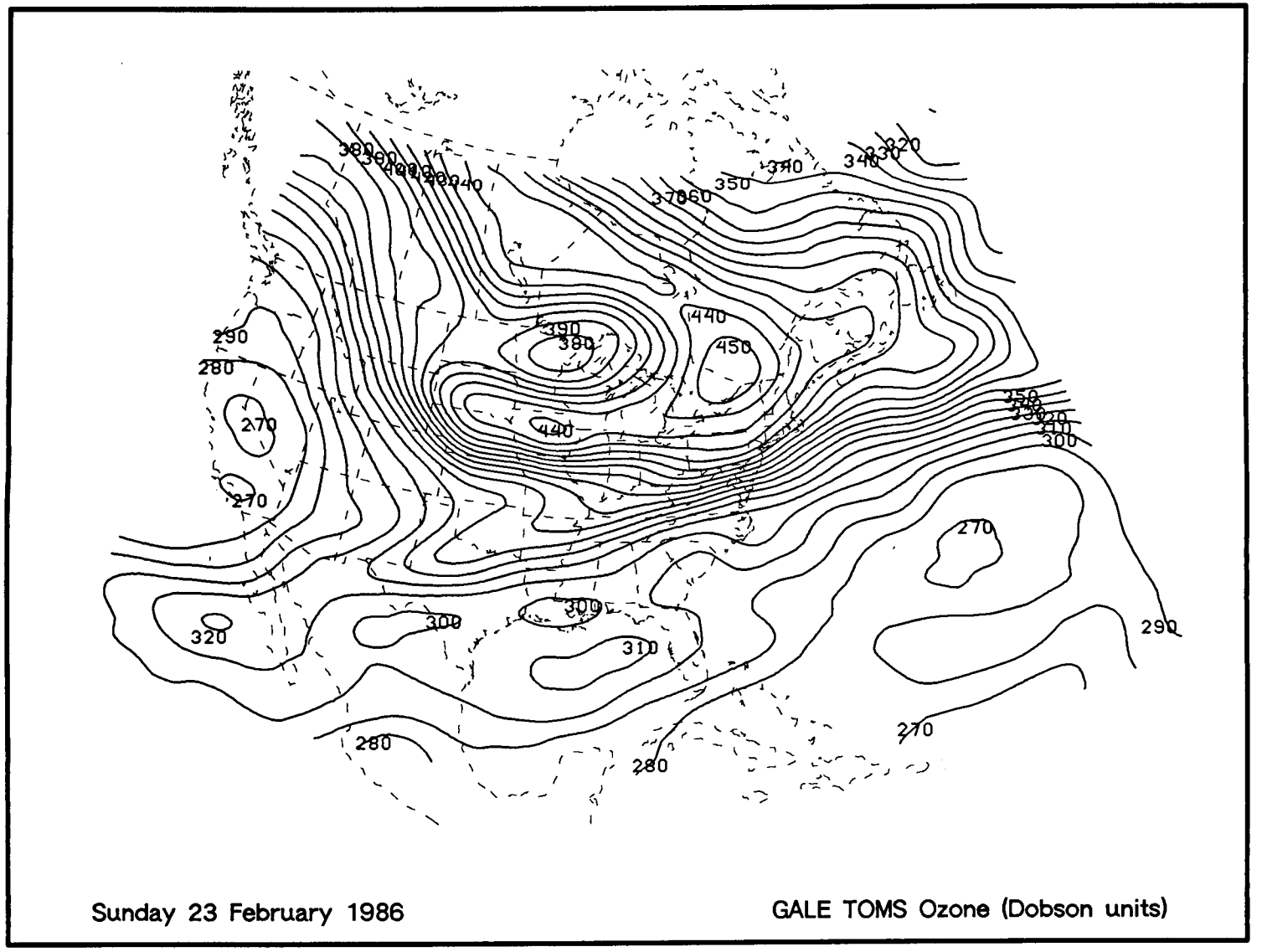

Figure 46. Ozone contour map (ten Dobson unit intervals) for GALE Day 40 Sunday, 23 February 1986.

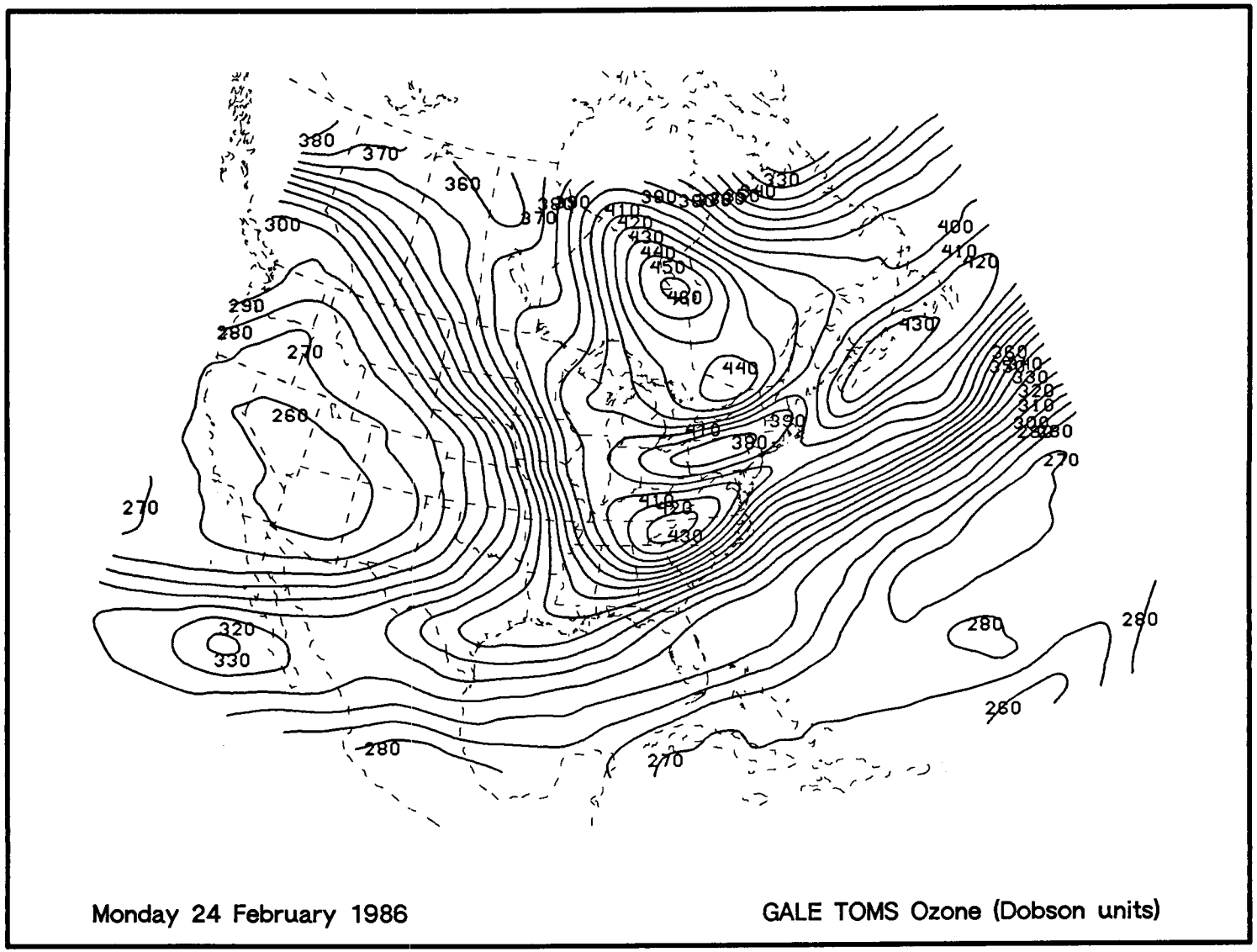

Figure 47. Ozone contour map (ten Dobson unit intervals) for GALE Day 41 Monday, 24 February 1986.

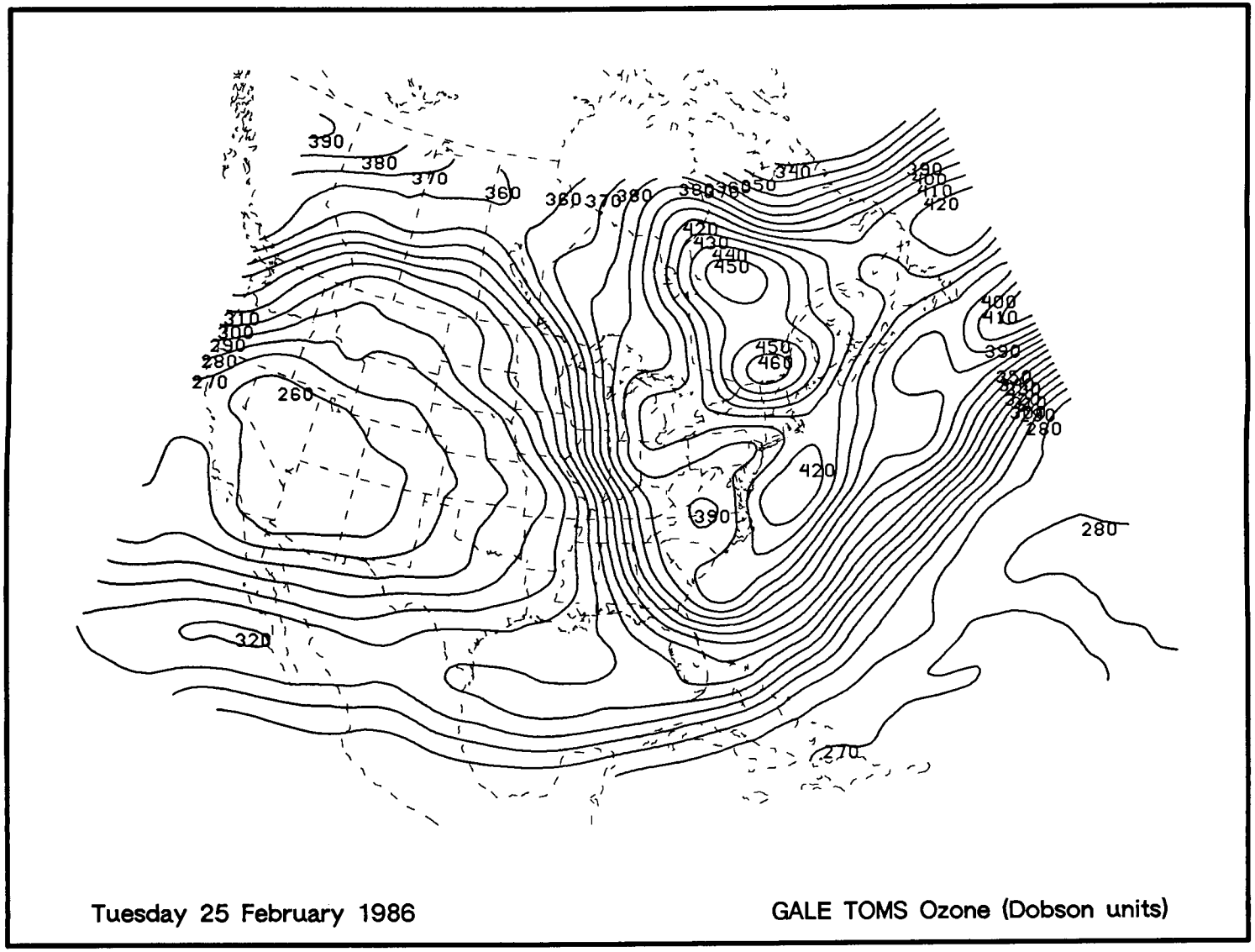

Figure 48. Ozone contour map (ten Dobson unit intervals) for GALE Day 42 Tuesday, 25 February 1986.

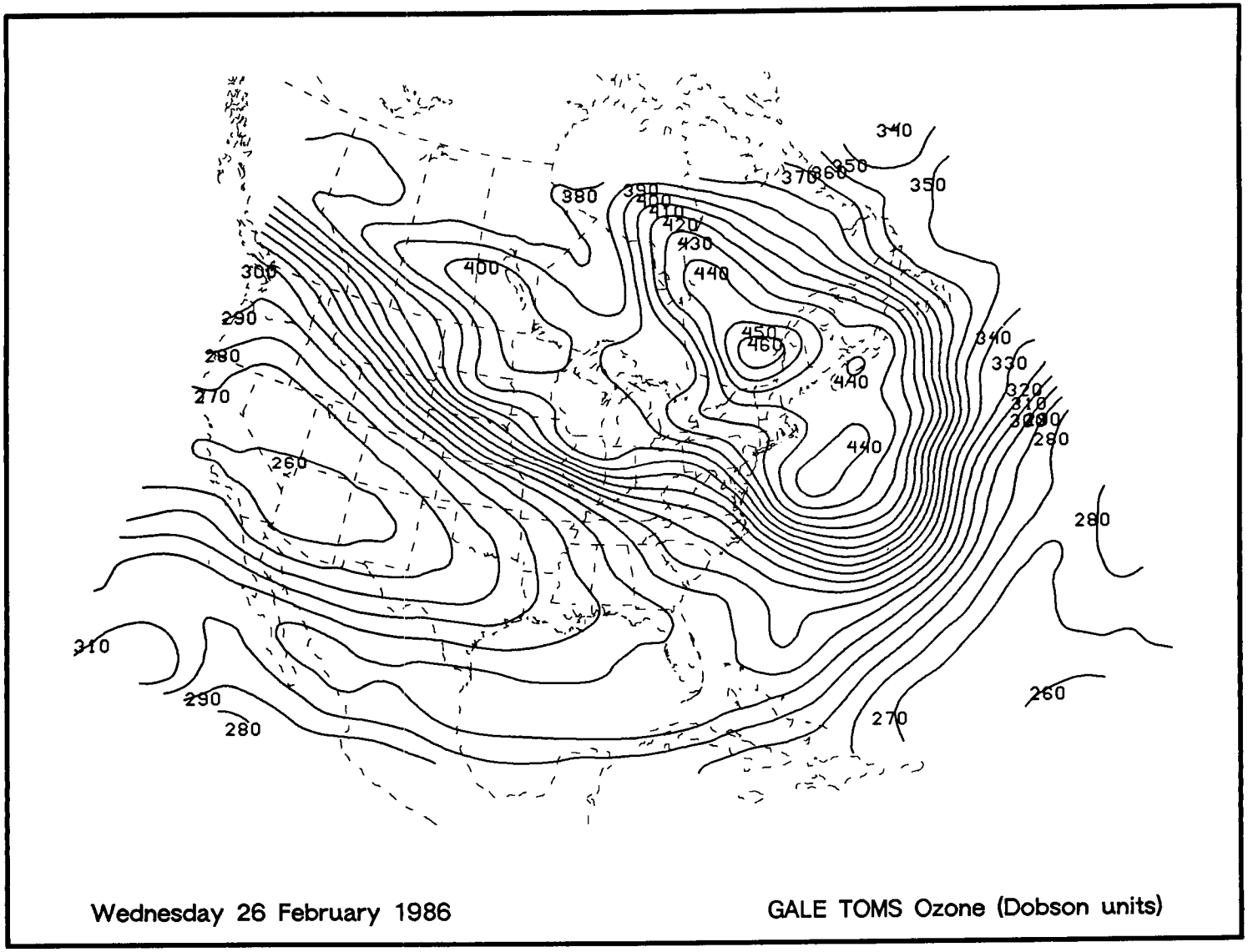

Figure 49. Ozone contour map (ten Dobson unit intervals) for GALE Day 43 Wednesday, 26 February 1986.

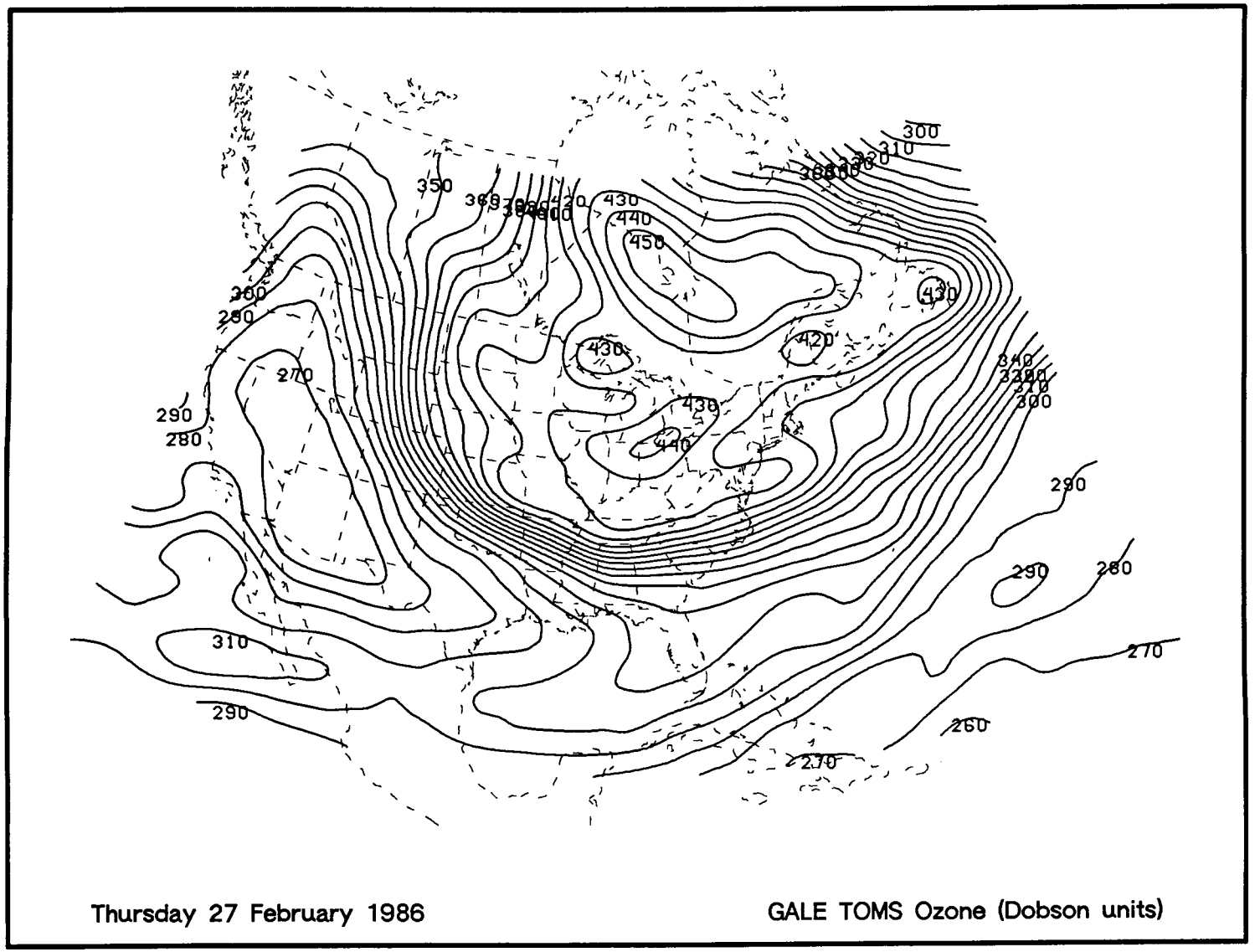

Figure 50. Ozone contour map (ten Dobson unit intervals) for GALE Day 44 Thursday, 27 February 1986.

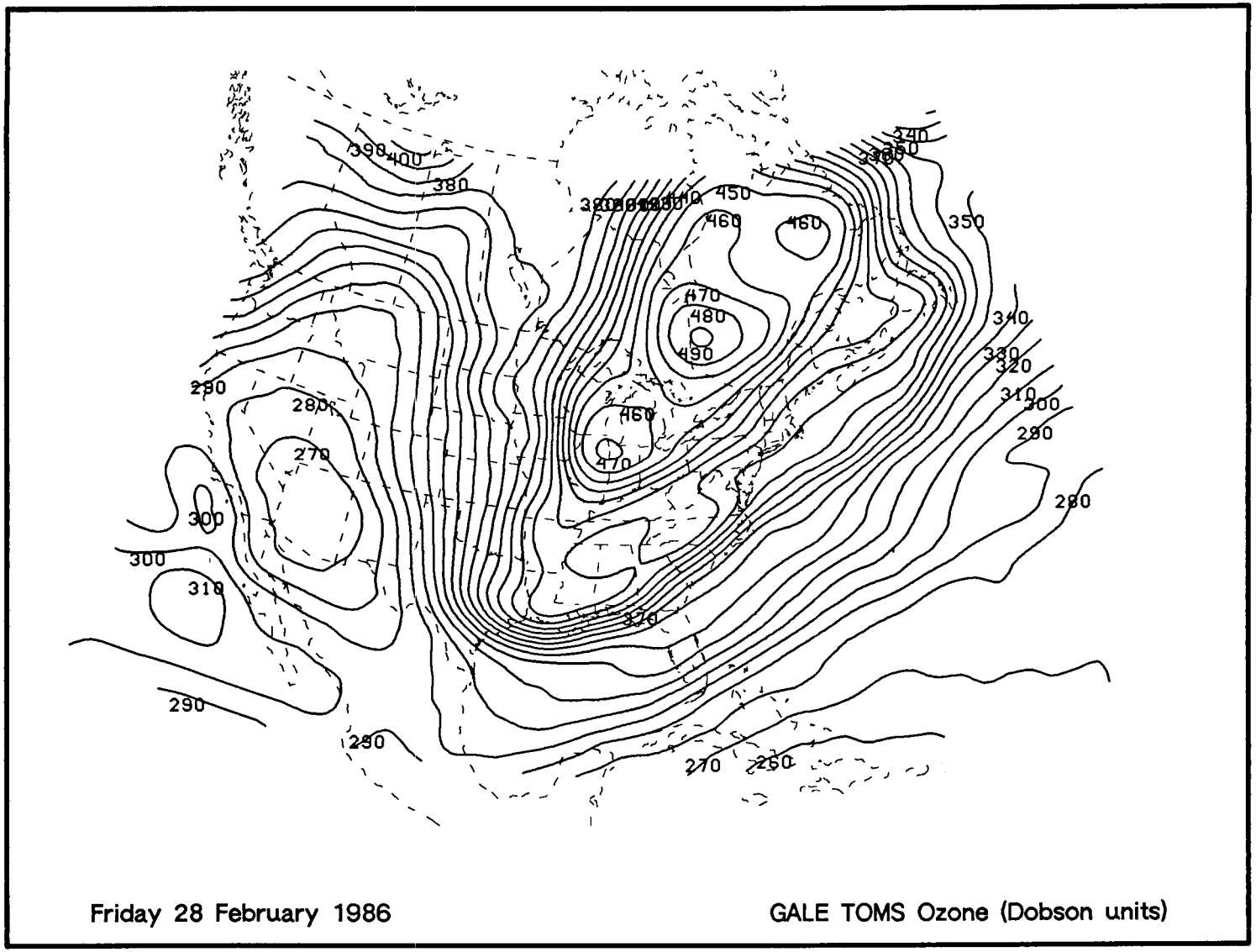

Figure 51. Ozone contour map (ten Dobson unit intervals) for GALE Day 45 Friday, 28 February 1986.

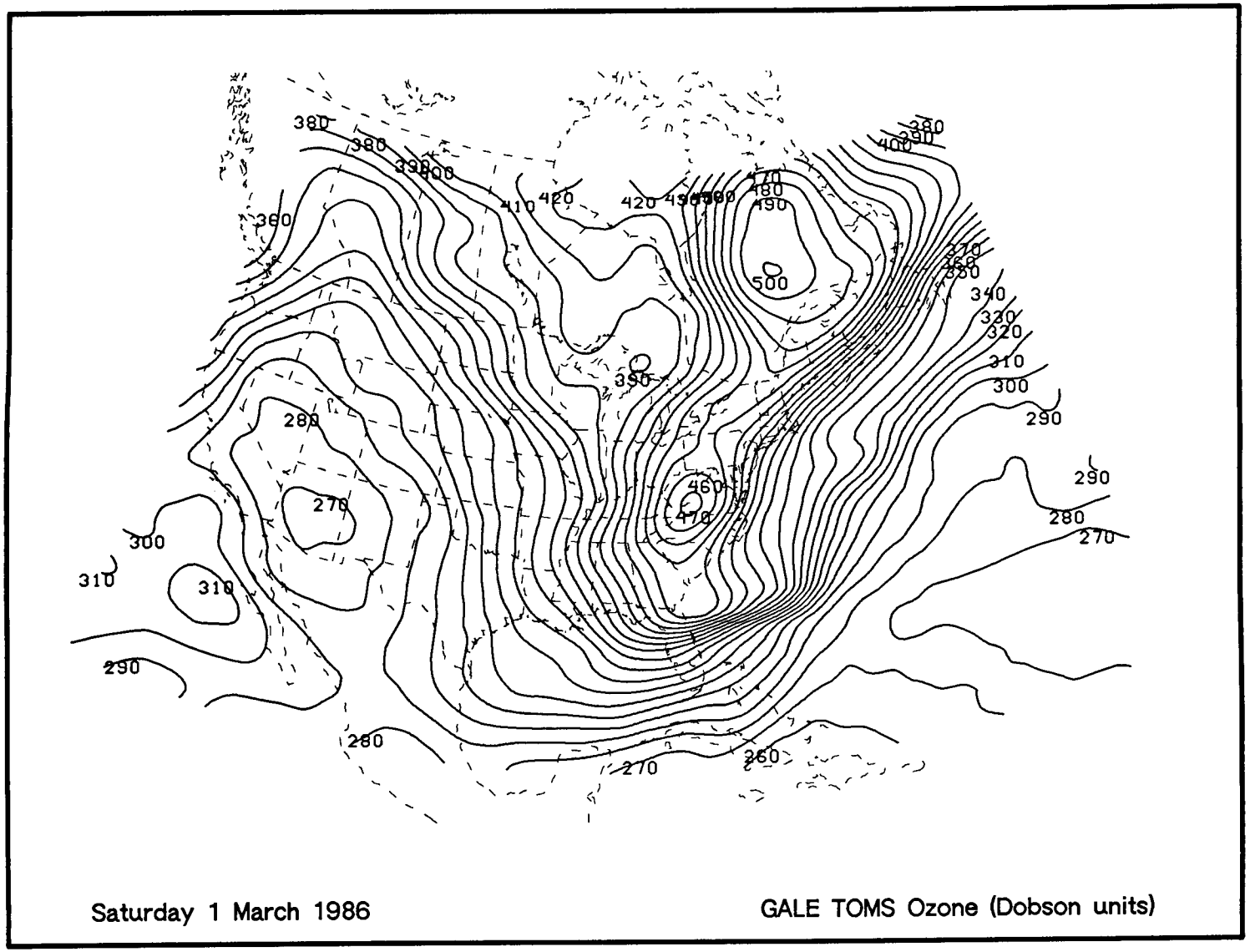

Figure 52. Ozone contour map (ten Dobson unit intervals) for GALE Day 46 Saturday, 1 March 1986.

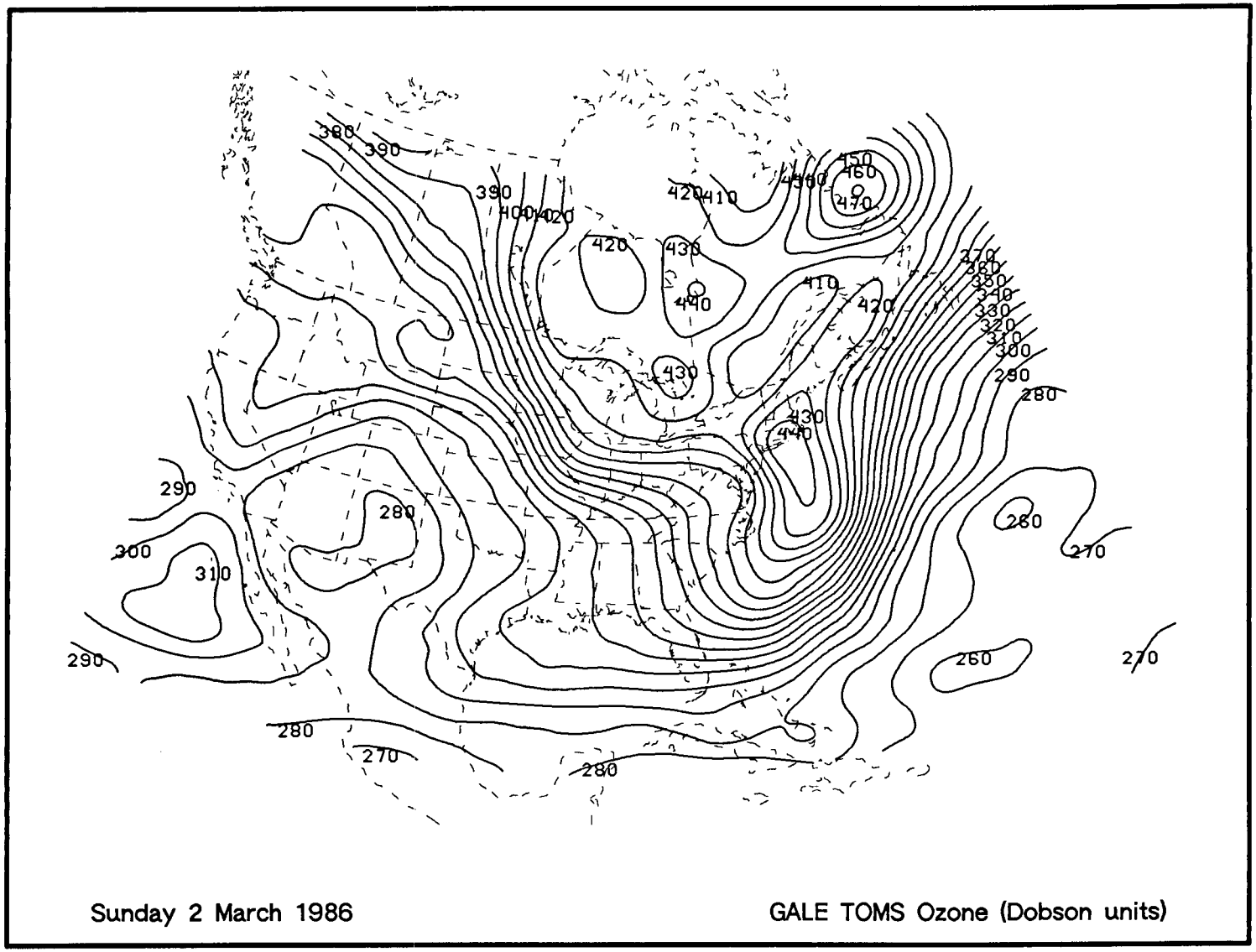

Figure 53. Ozone contour map (ten Dobson unit intervals) for GALE Day 47 Sunday, 2 March 1986.

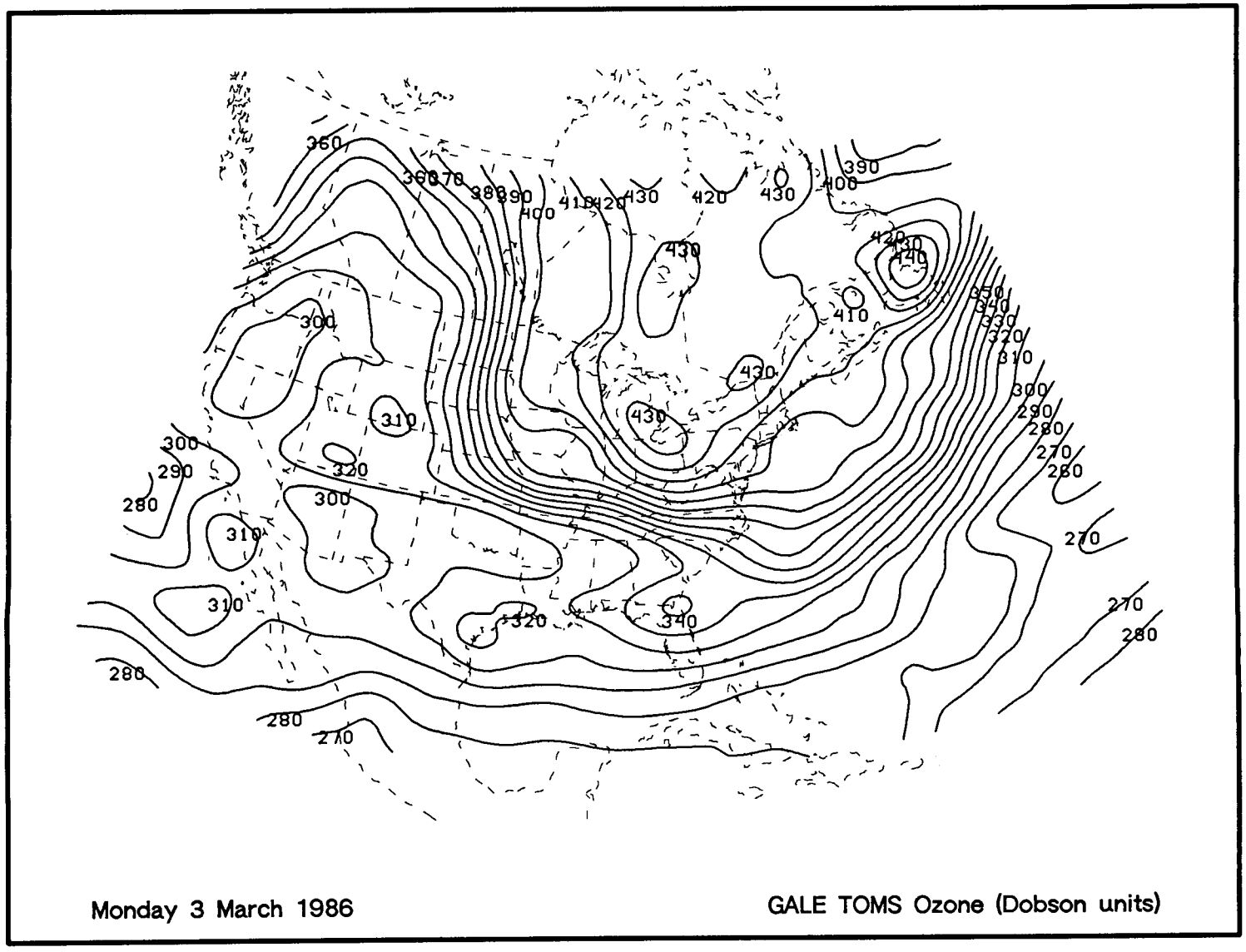

Figure 54. Ozone contour map (ten Dobson unit intervals) for GALE Day 48 Monday, 3 March 1986.

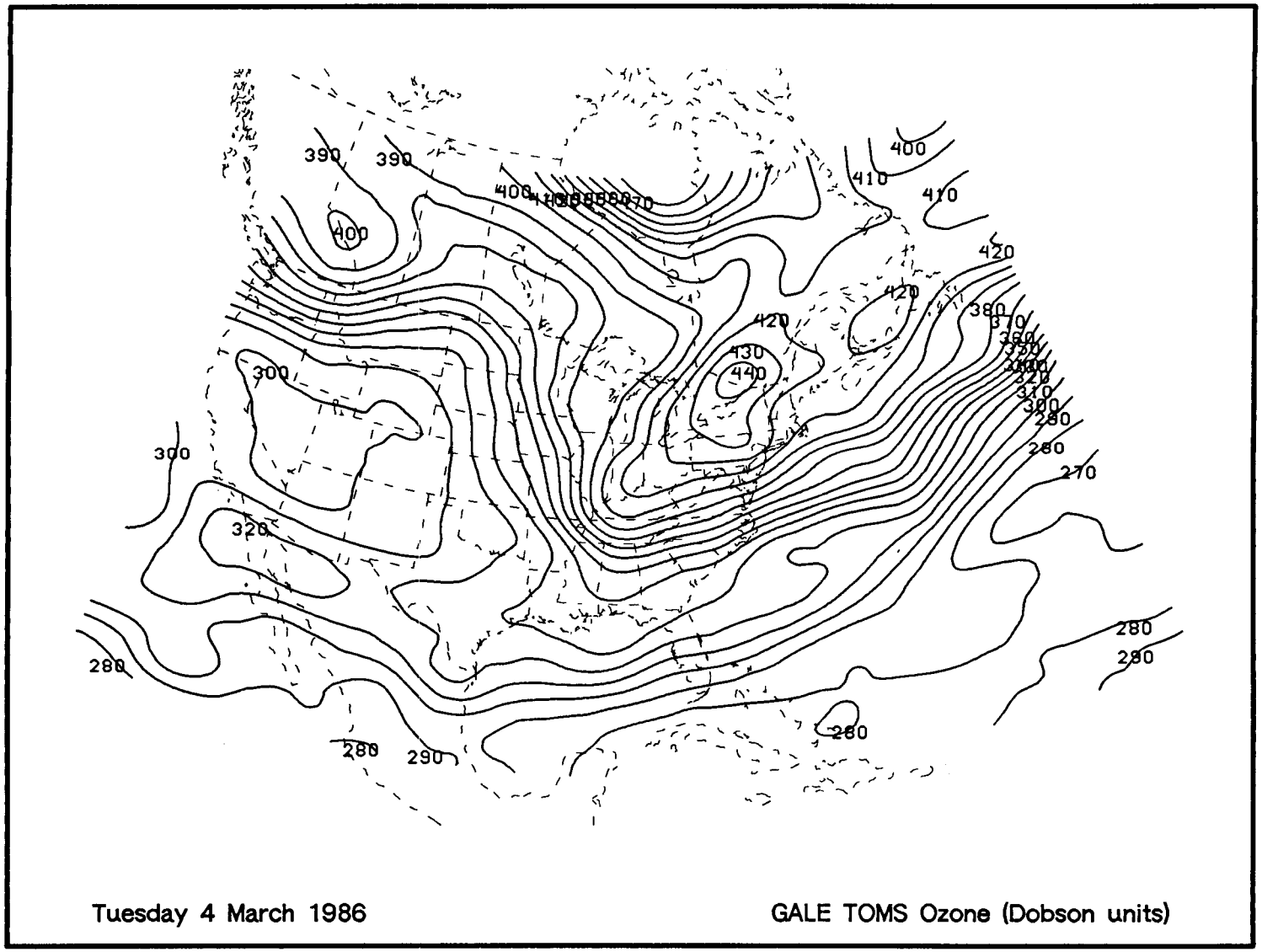

Figure 55. Ozone contour map (ten Dobson unit intervals) for GALE Day 49 Tuesday, 4 March 1986.

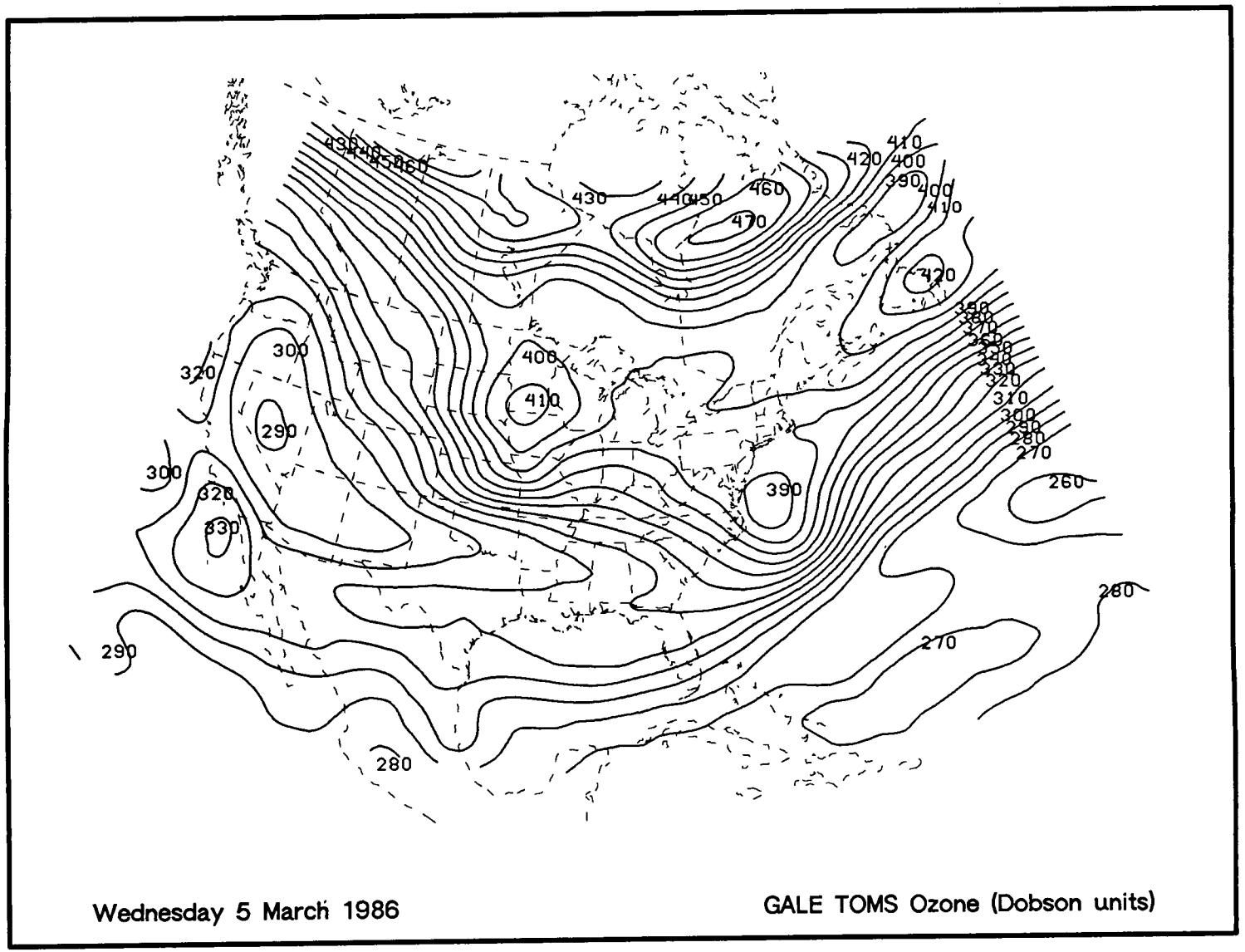

Figure 56. Ozone contour map (ten Dobson unit intervals) for GALE Day 50 Wednesday, 5 March 1986.

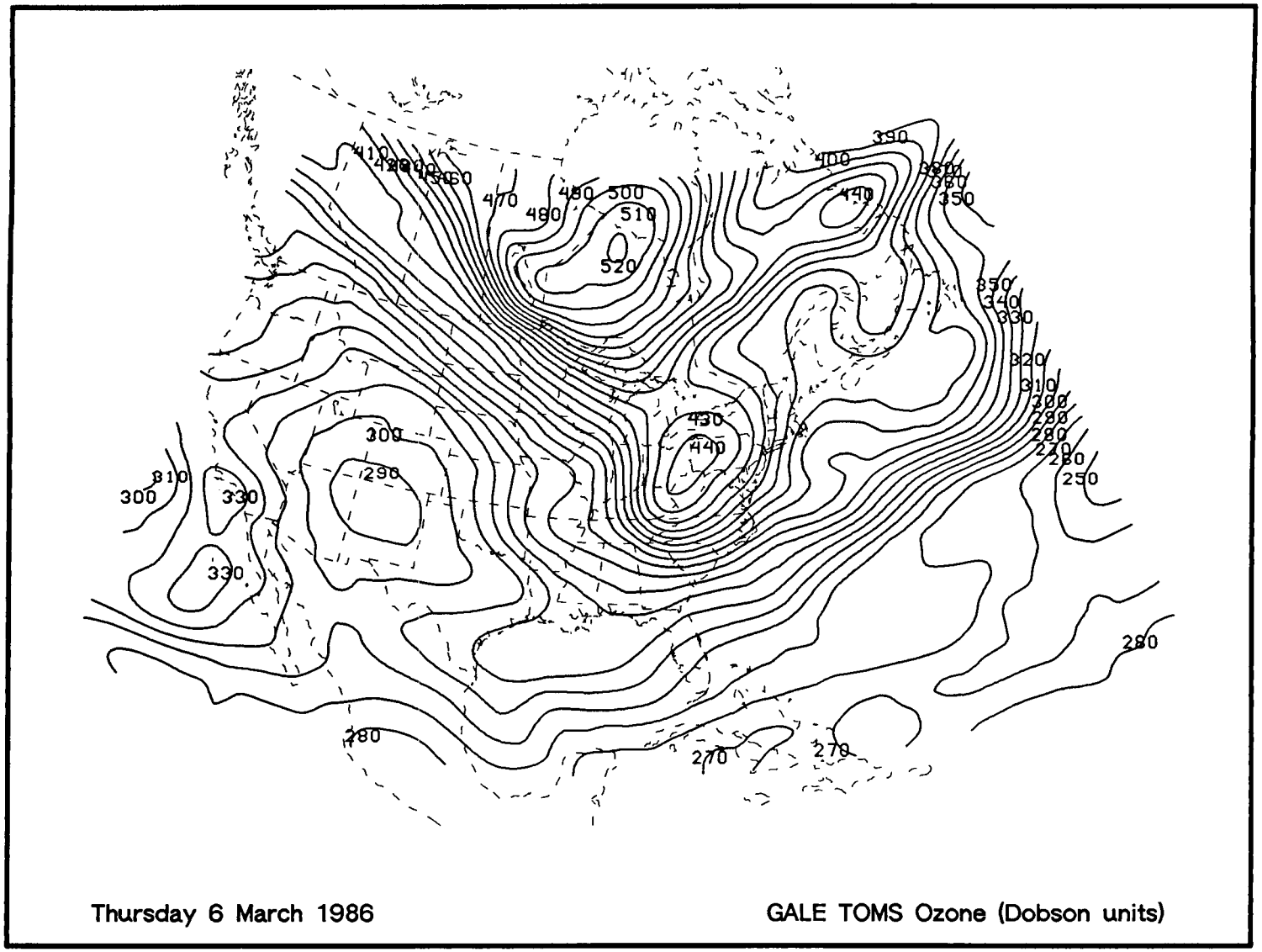

Figure 57. Ozone contour map (ten Dobson unit intervals) for GALE Day 51 Thursday, 6 March 1986.

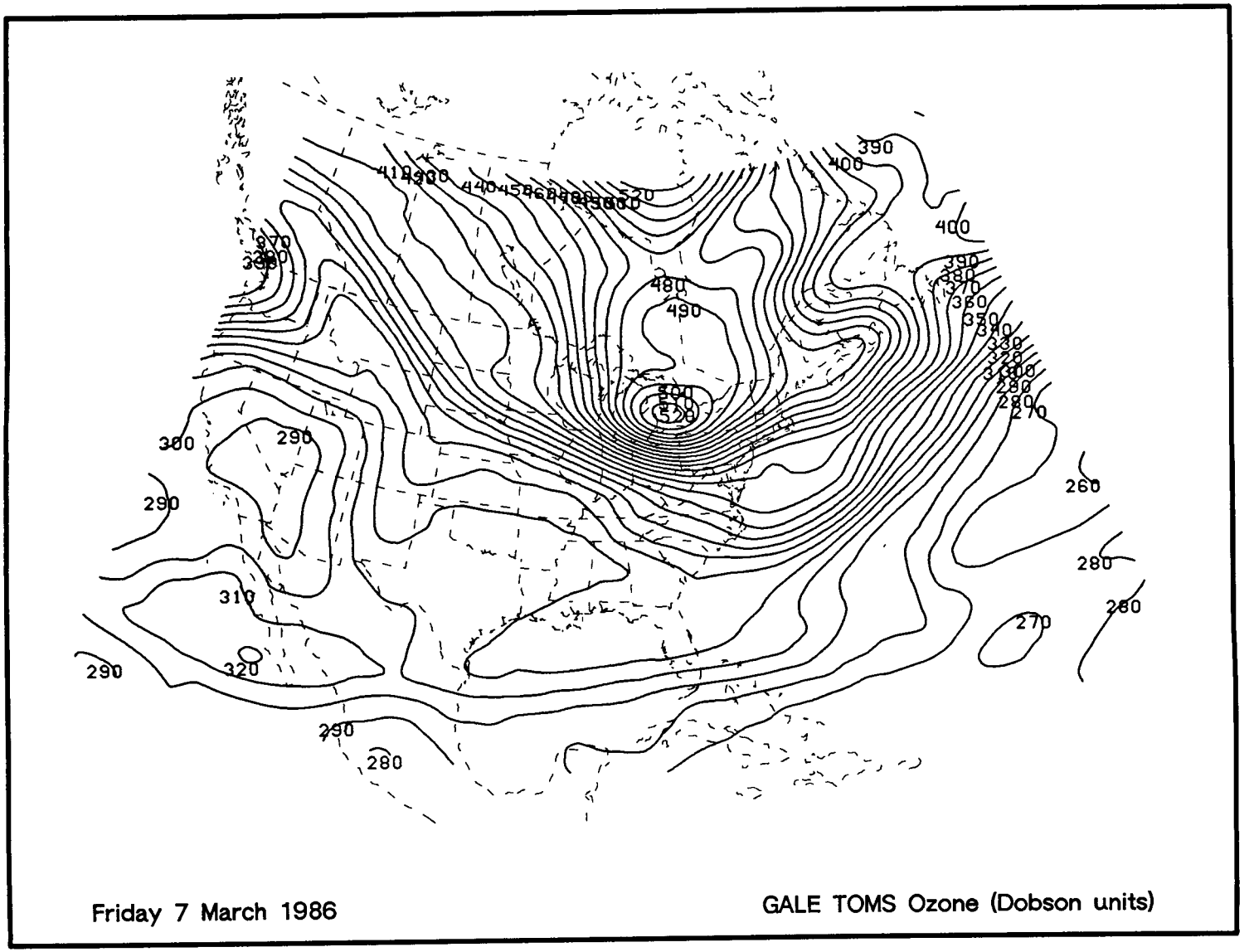

Figure 58. Ozone contour map (ten Dobson unit intervals) for GALE Day 52 Friday, 7 March 1986.

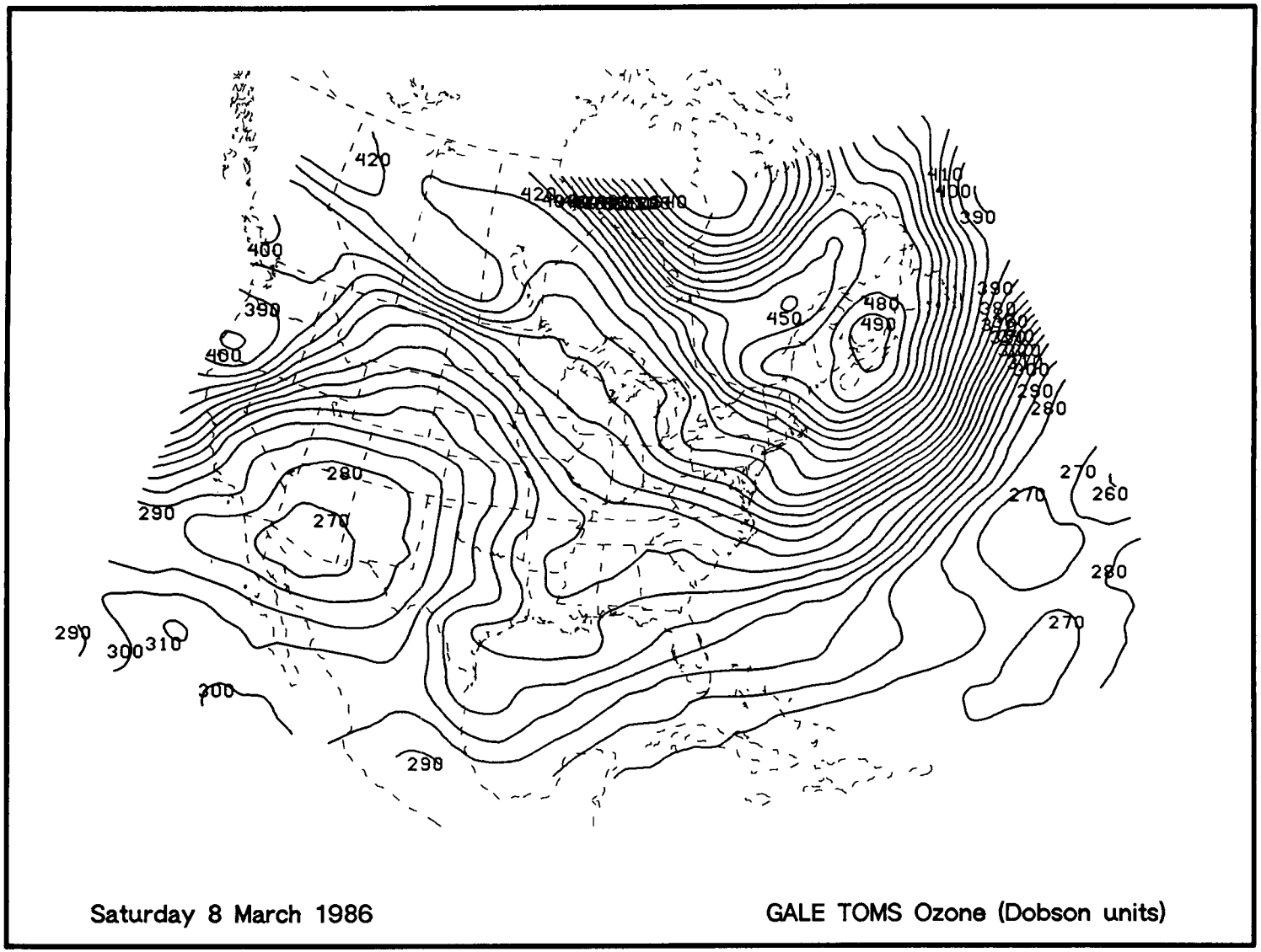

Figure 59. Ozone contour map (ten Dobson unit intervals) for GALE Day 53 Saturday, 8 March 1986.

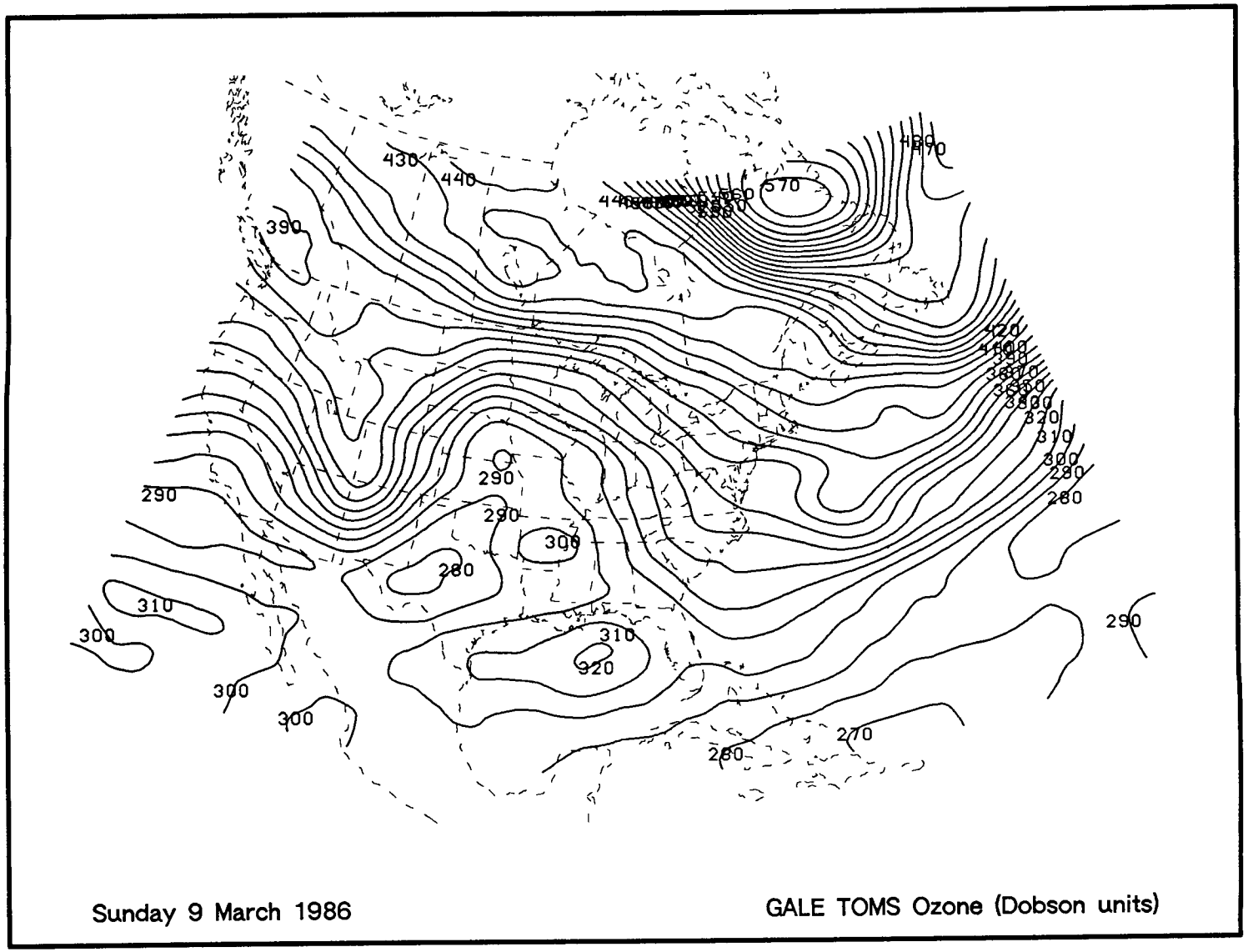

Figure 60. Ozone contour map (ten Dobson unit intervals) for GALE Day 54 Sunday, 9 March 1986.

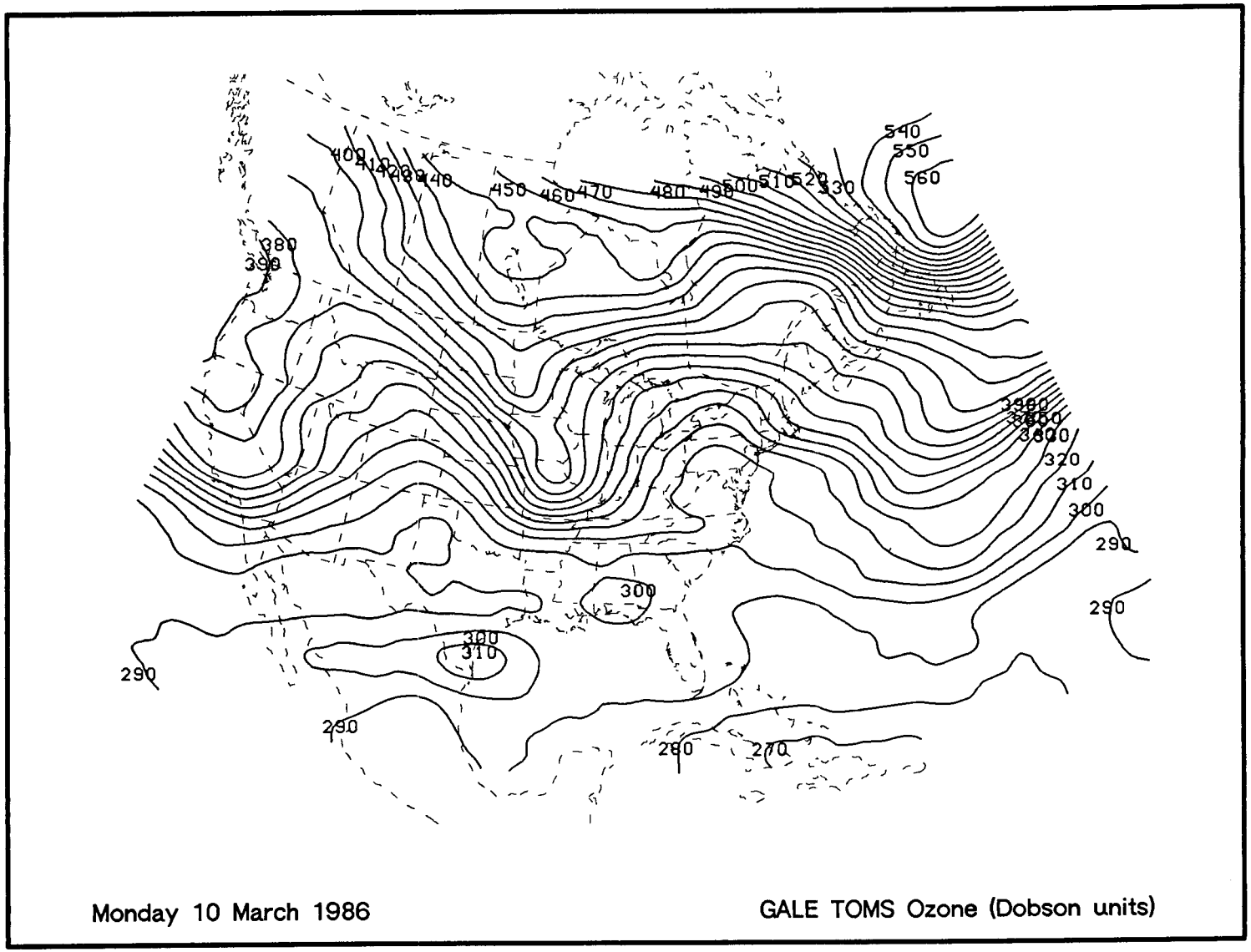

Figure 61. Ozone contour map (ten Dobson unit intervals) for GALE Day 55 Monday, 10 March 1986.

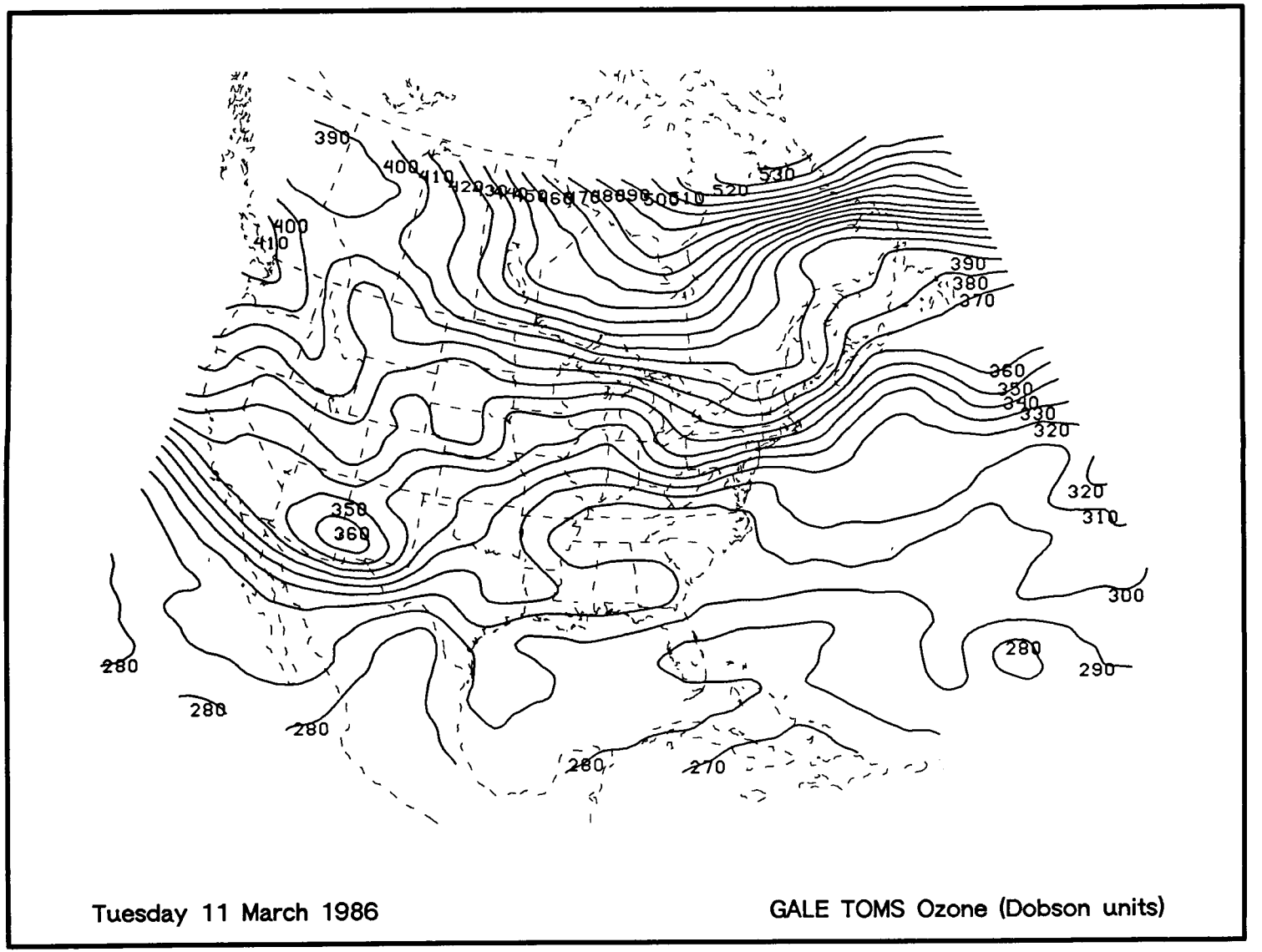

Figure 62. Ozone contour map (ten Dobson unit intervals) for GALE Day 56 Tuesday, 11 March 1986.

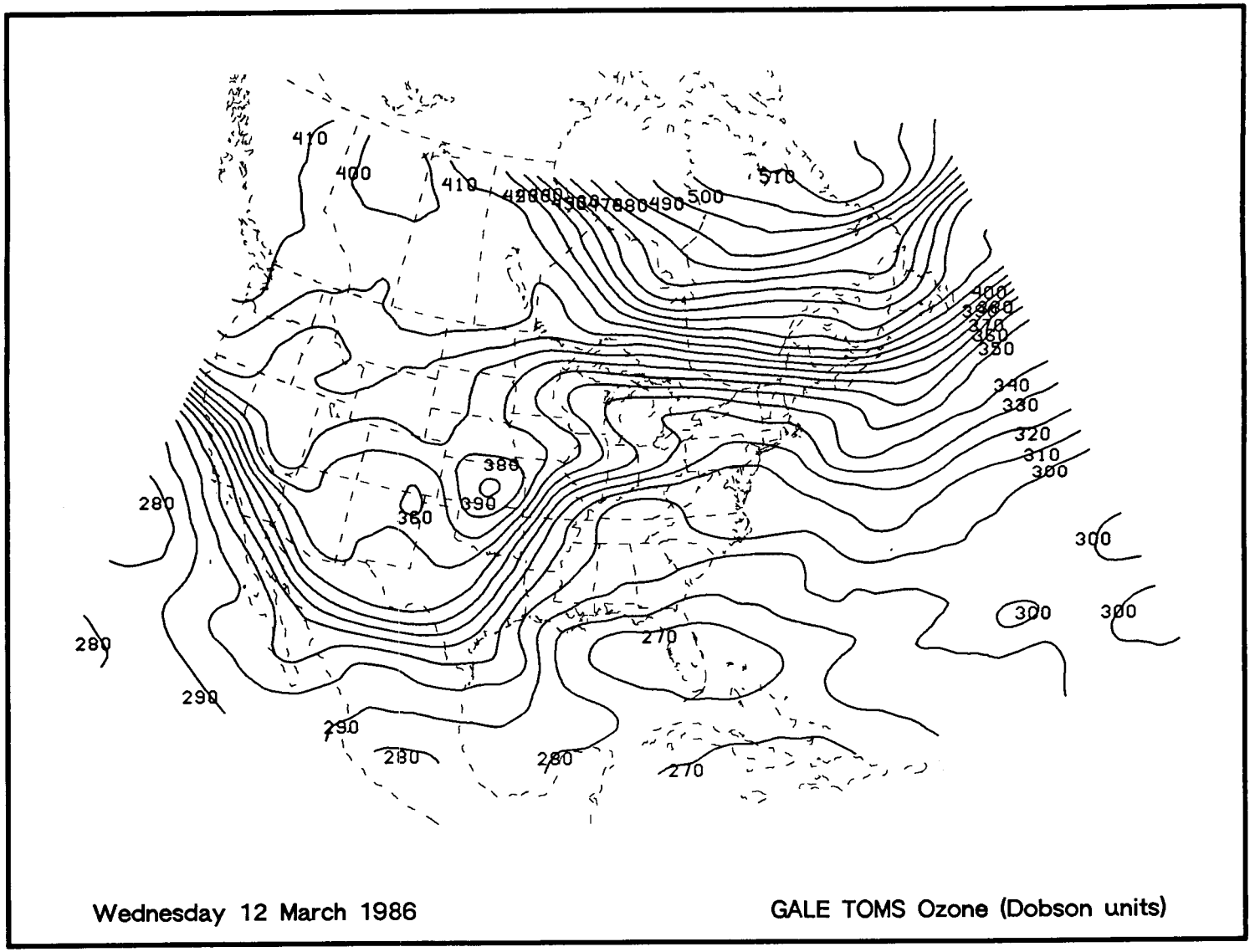

Figure 63. Ozone contour map (ten Dobson unit intervals) for GALE Day 57 Wednesday, 12 March 1986.

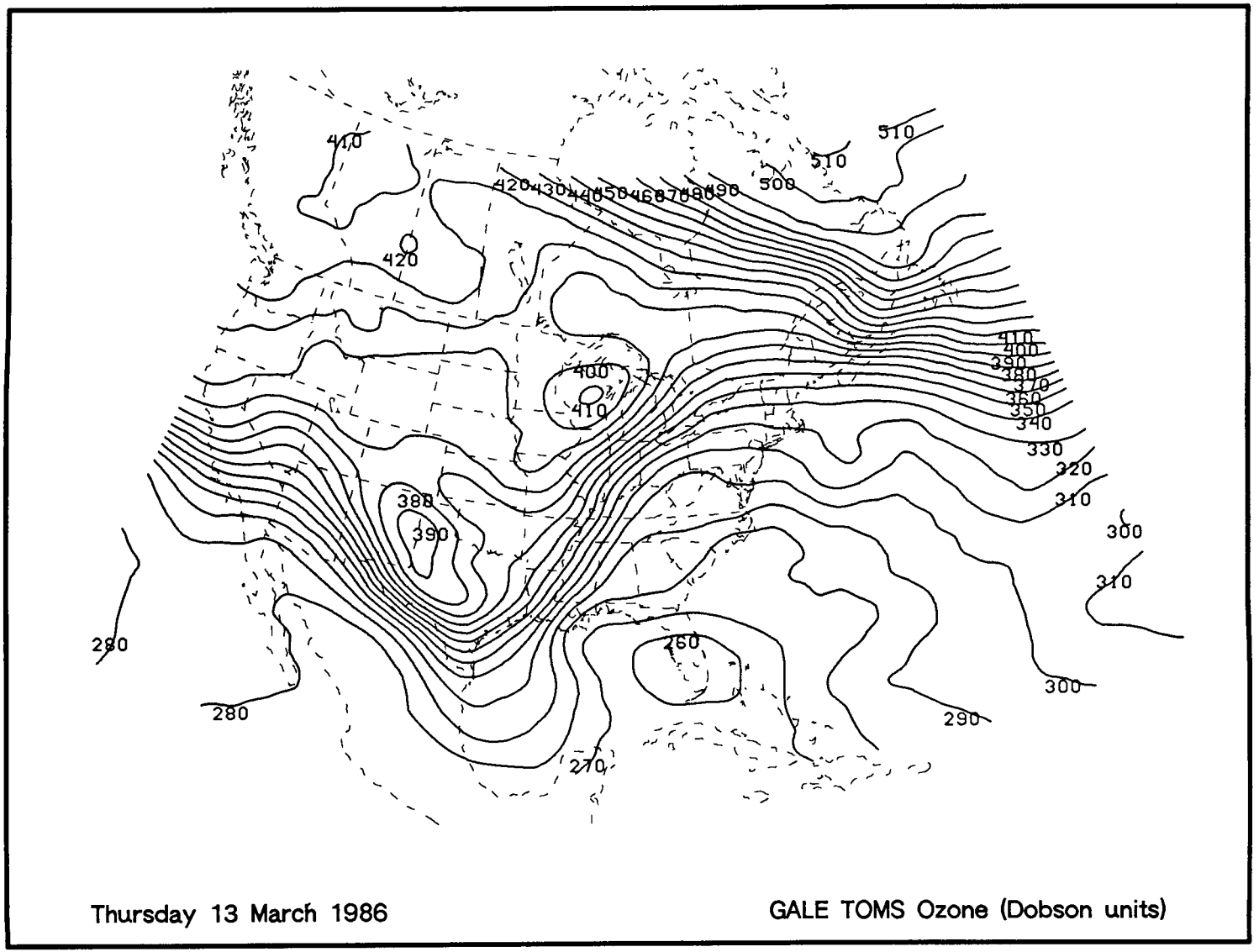

Figure 64. Ozone contour map (ten Dobson unit intervals) for GALE Day 58 Thursday, 13 March 1986.

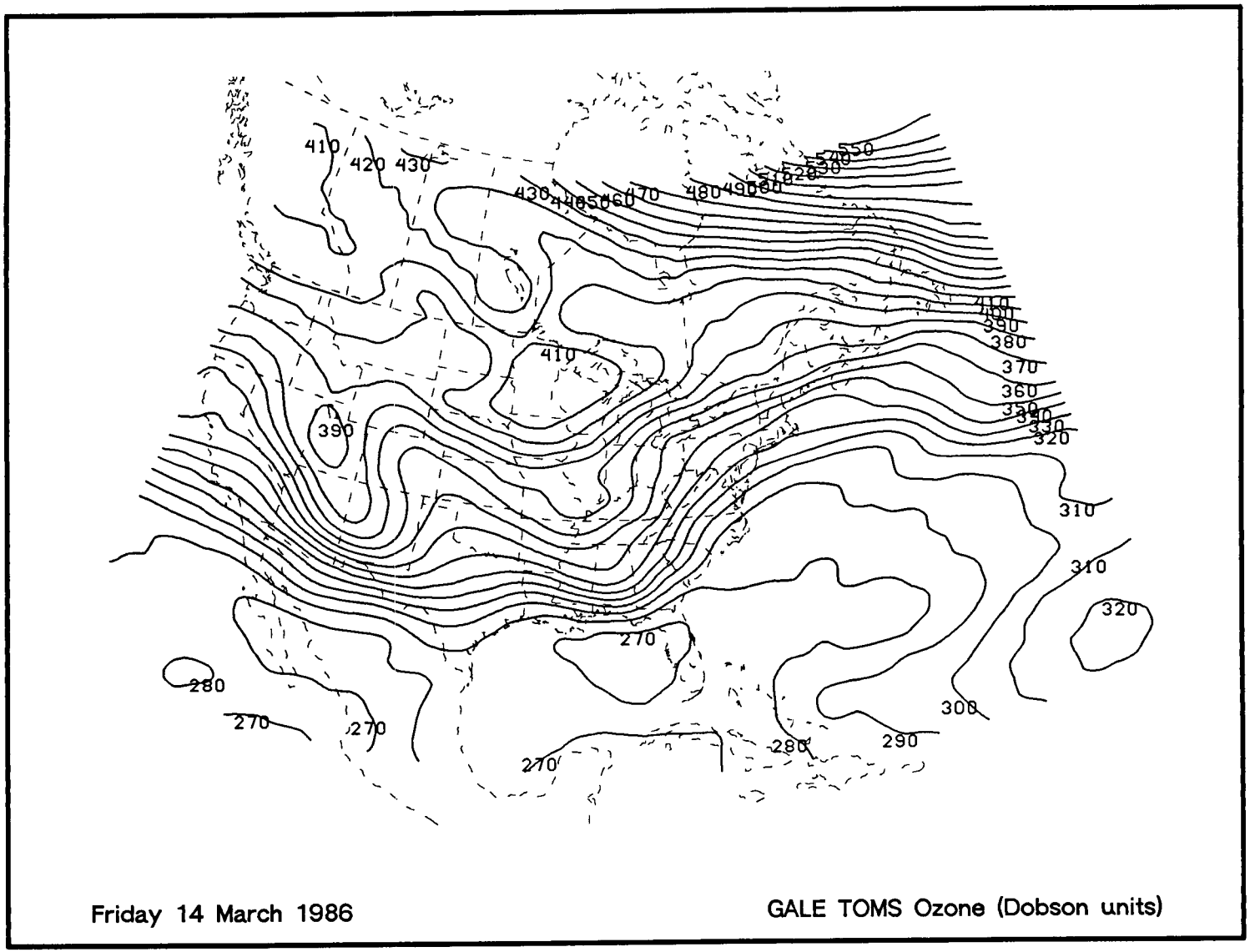

Figure 65. Ozone contour map (ten Dobson unit intervals) for GALE Day 59 Friday, 14 March 1986.

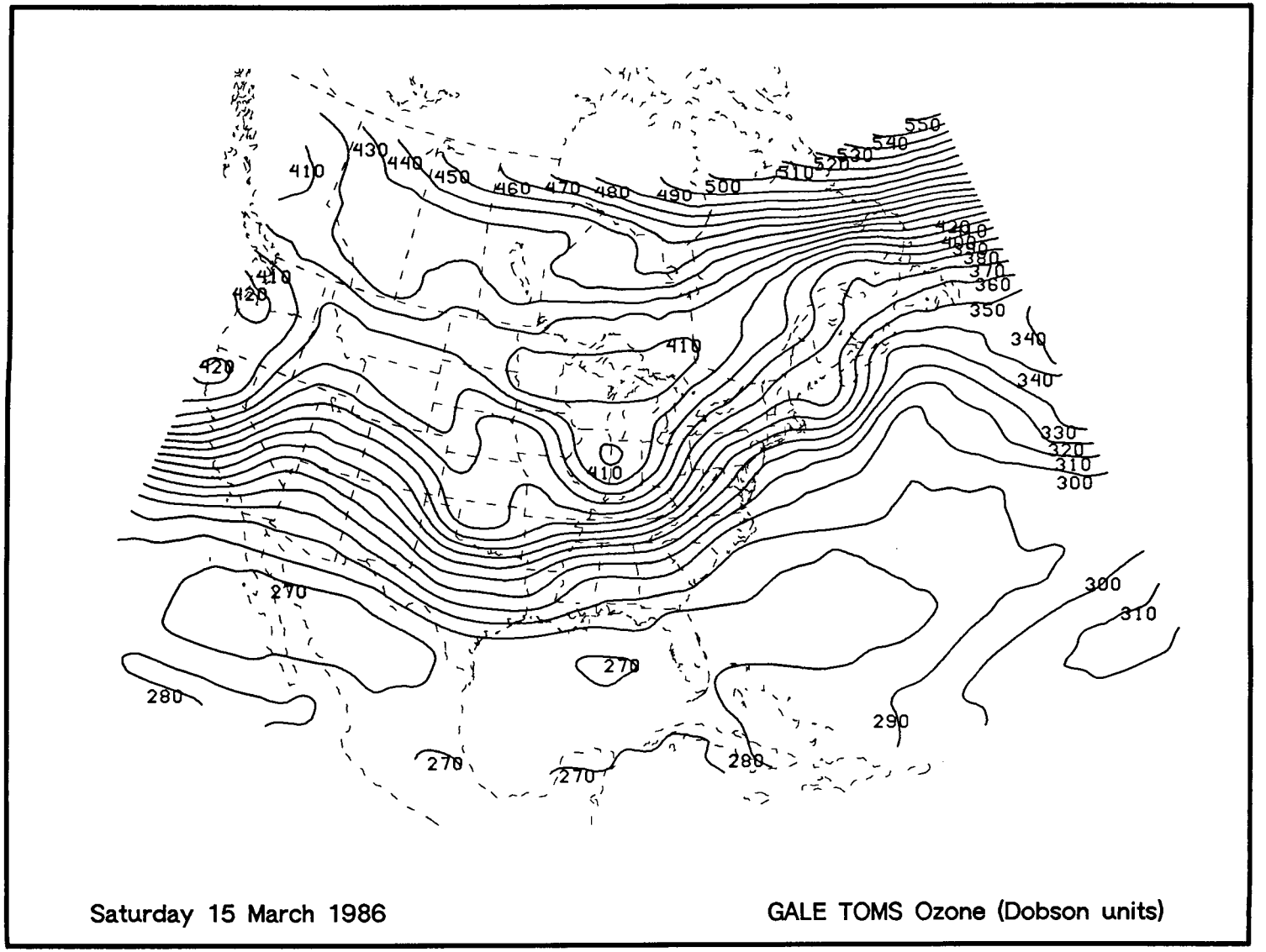

Figure 66. Ozone contour map (ten Dobson unit intervals) for GALE Day 60 Saturday, 15 March 1986.

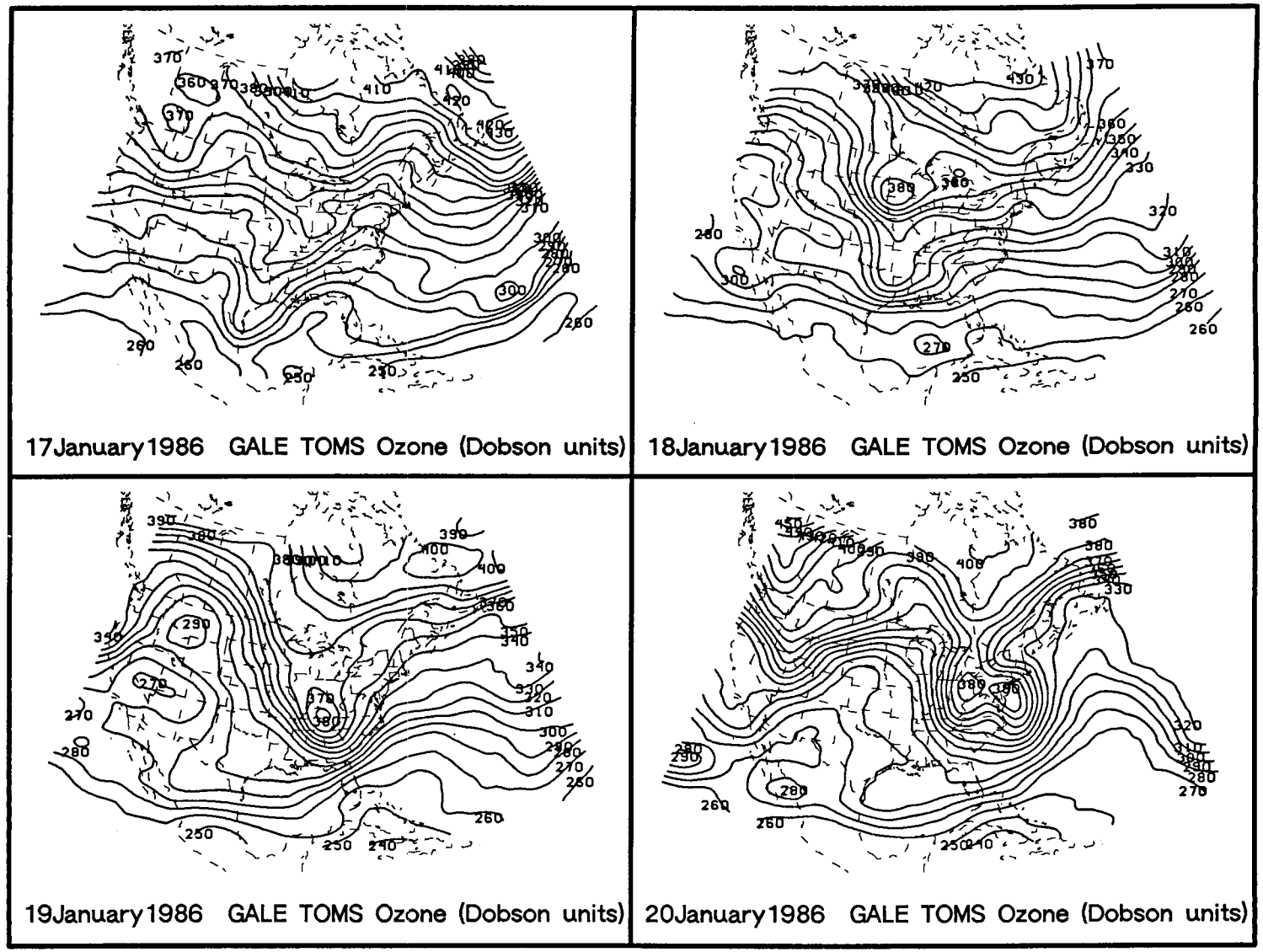

Figure 67. Ozone contour maps (ten Dobson unit intervals) from 17 January through 20 January 1986 covering GALE IOP 1.

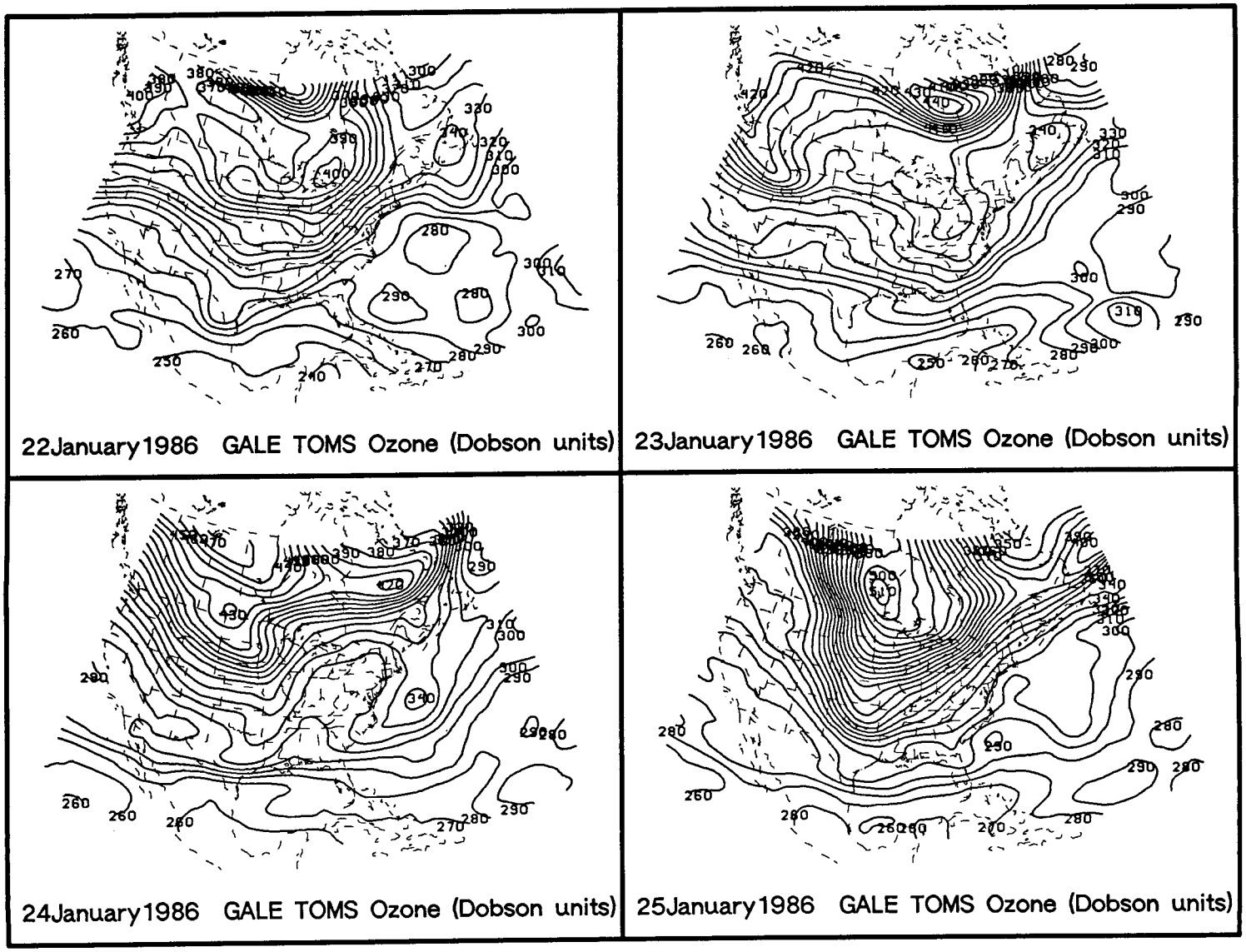

Figure 68. Ozone contour maps (ten Dobson unit intervals) from 22 January through 25 January 1986 covering the first half of GALE IOP 2.

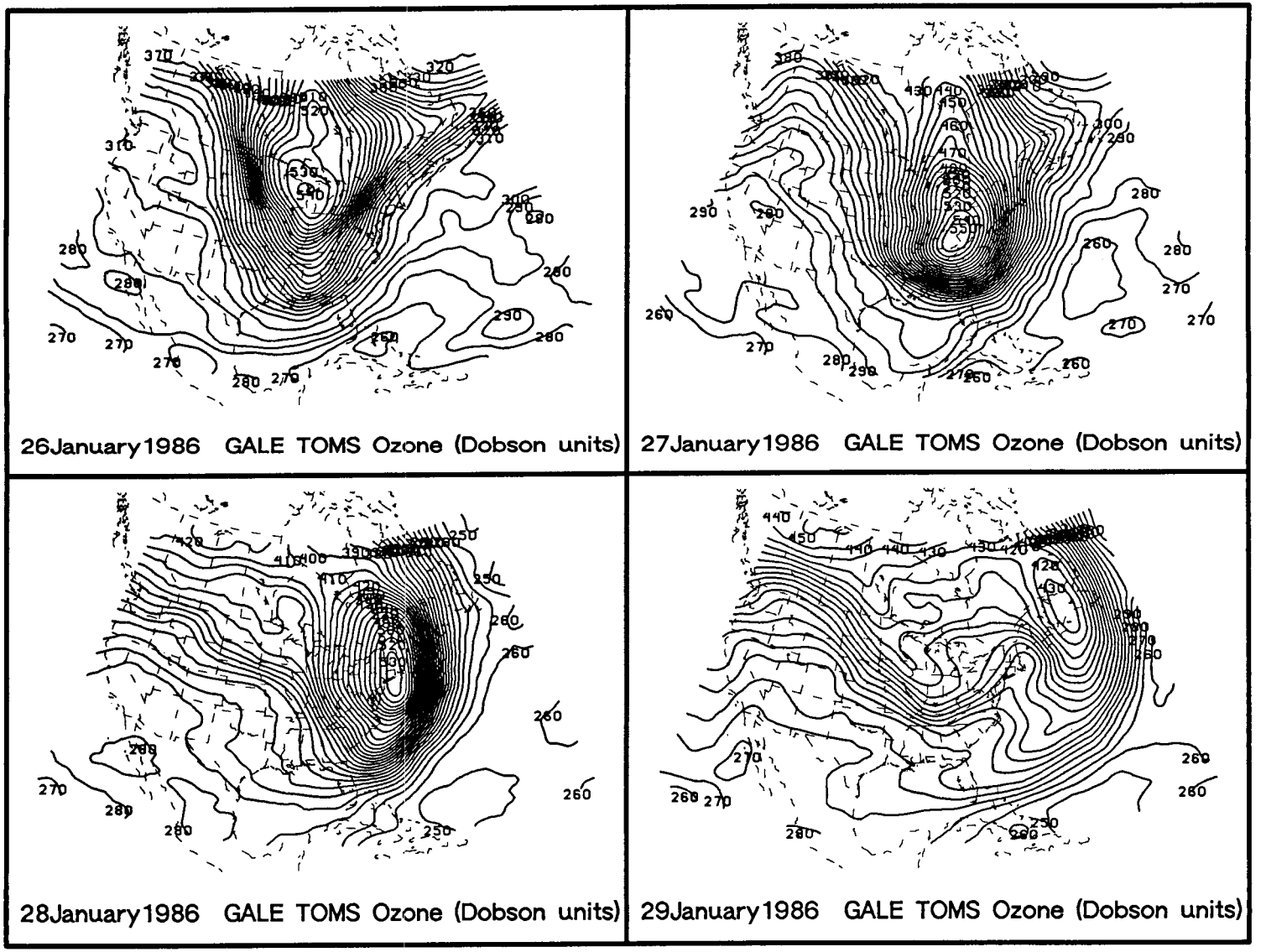

Figure 69. Ozone contour maps (ten Dobson unit intervals) from 26 January through 29 January 1986 covering the second half of GALE IOP 2.

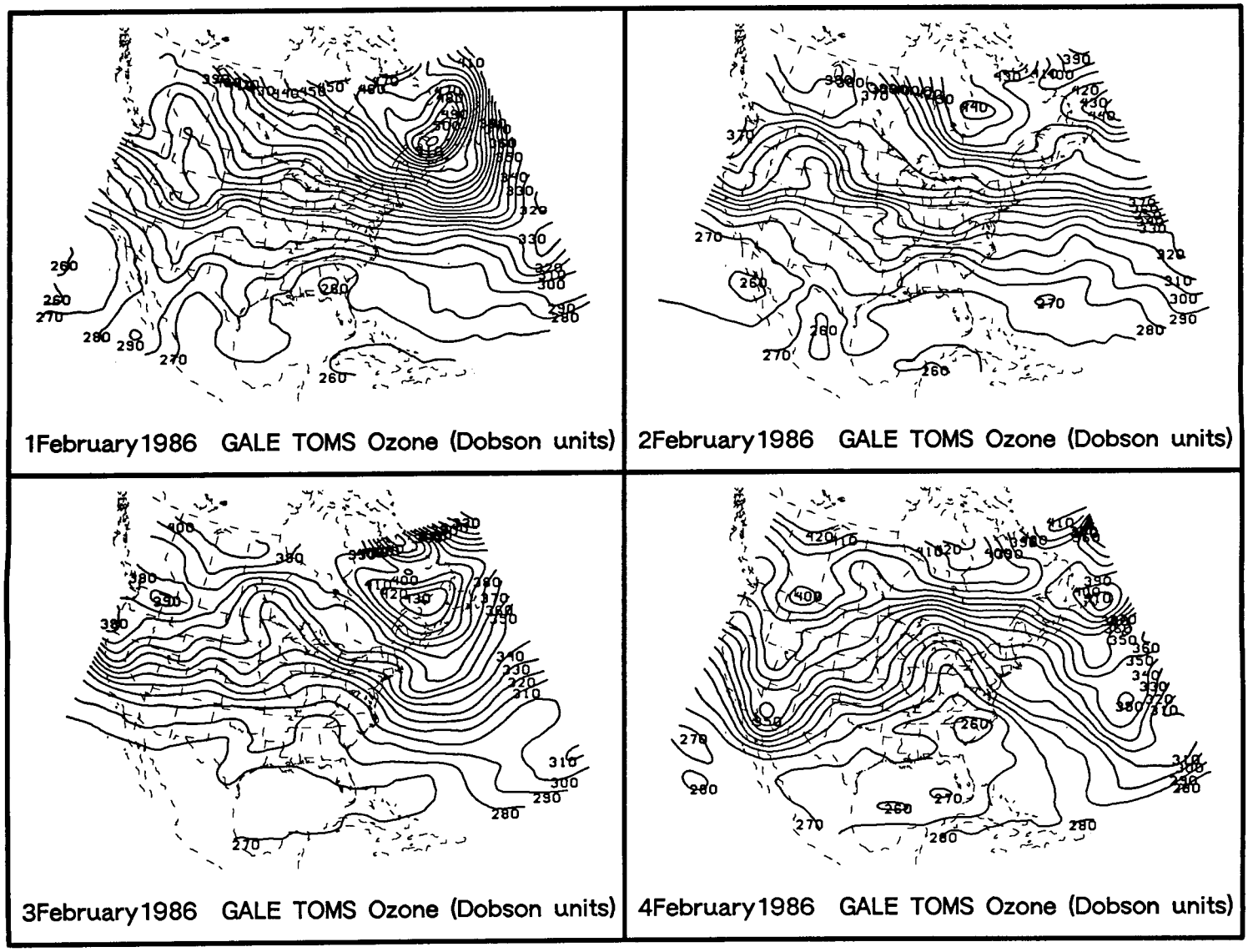

Figure 70. Ozone contour maps (ten Dobson unit intervals) from 1 February through 4 February 1986 covering GALE IOP 3.

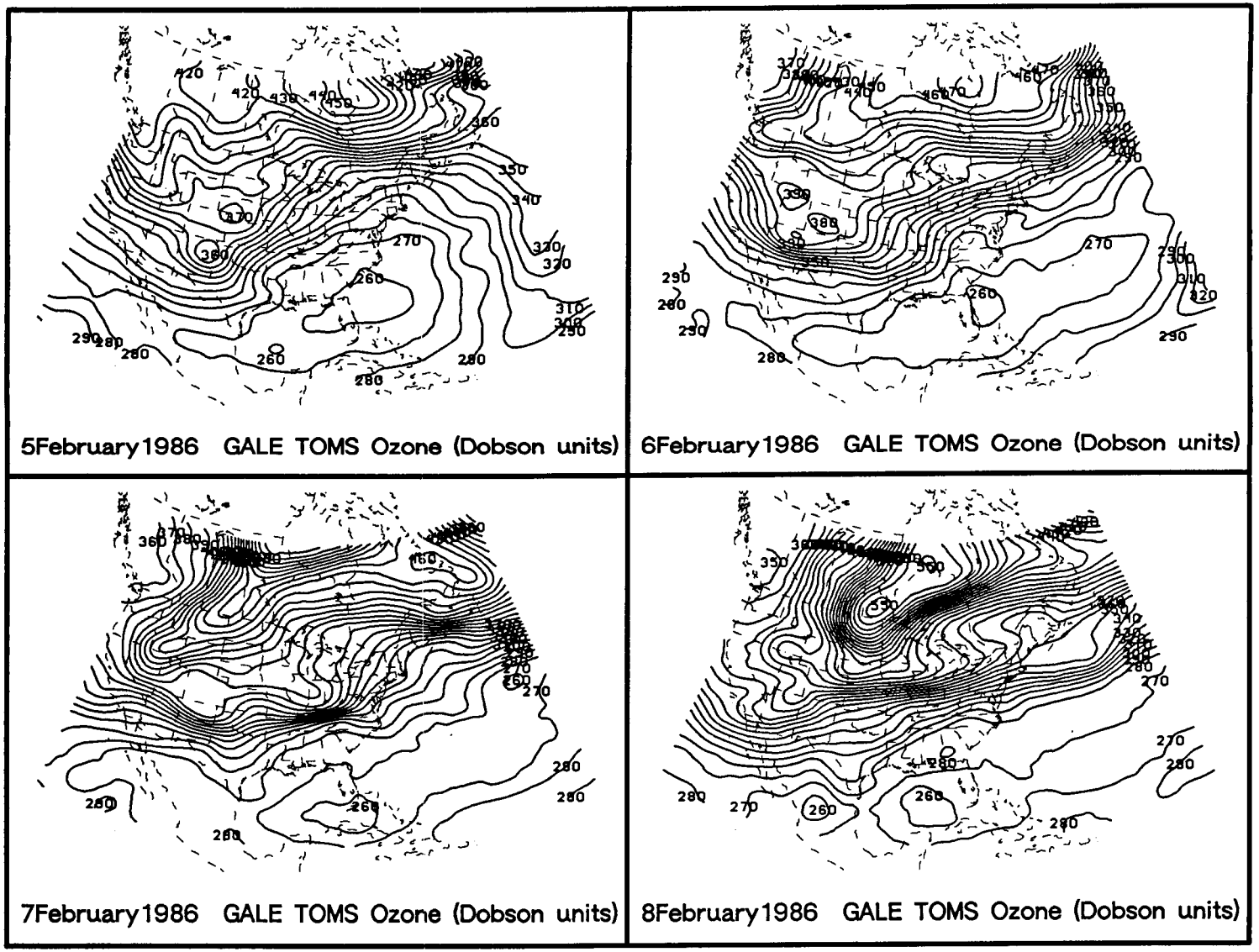

Figure 71. Ozone contour maps (ten Dobson unit intervals) from 5 February through 8 February 1986 covering GALE IOP 4.

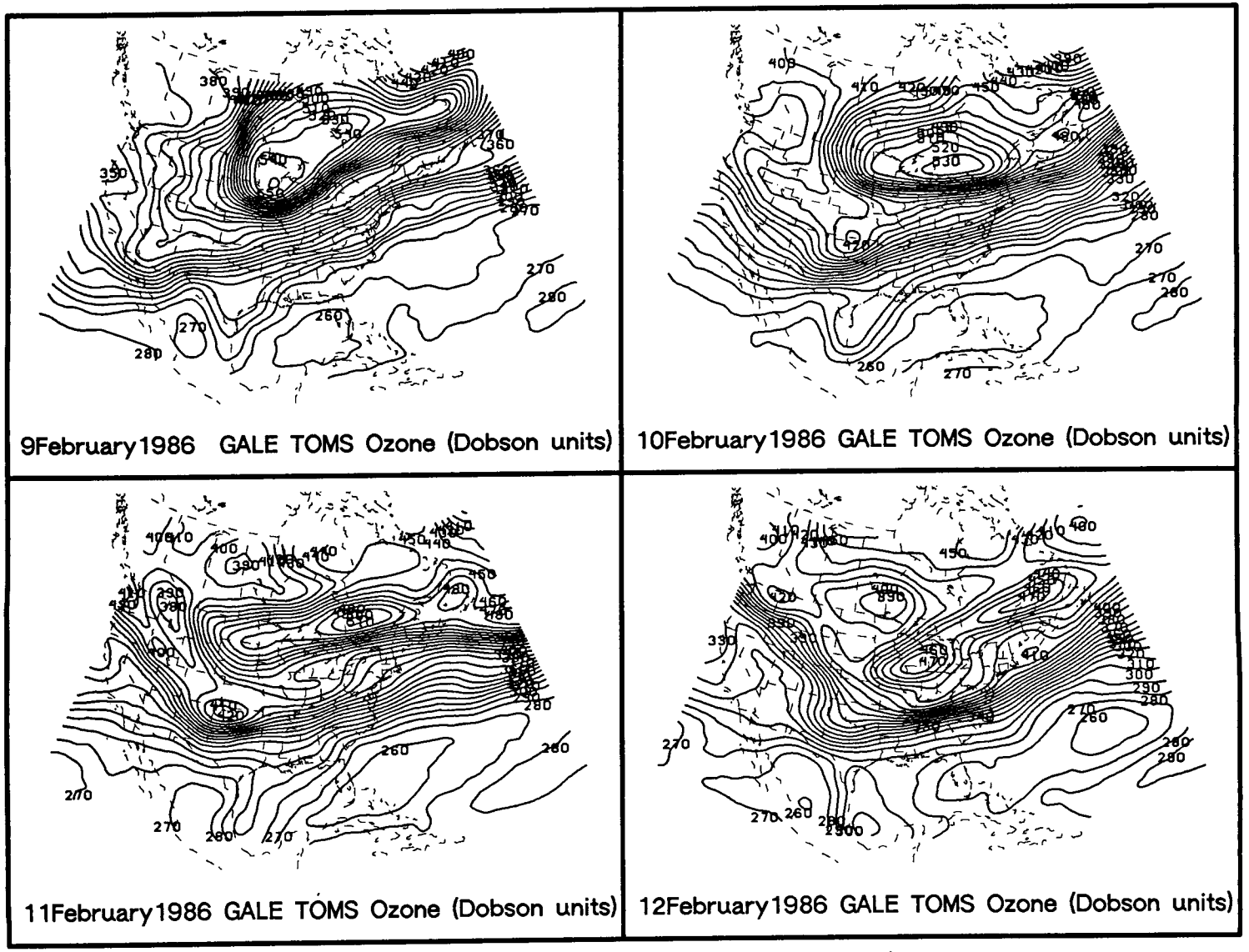

Figure 72. Ozone contour maps (ten Dobson unit intervals) from 9 February through 12 February 1986 covering GALE IOP 5.

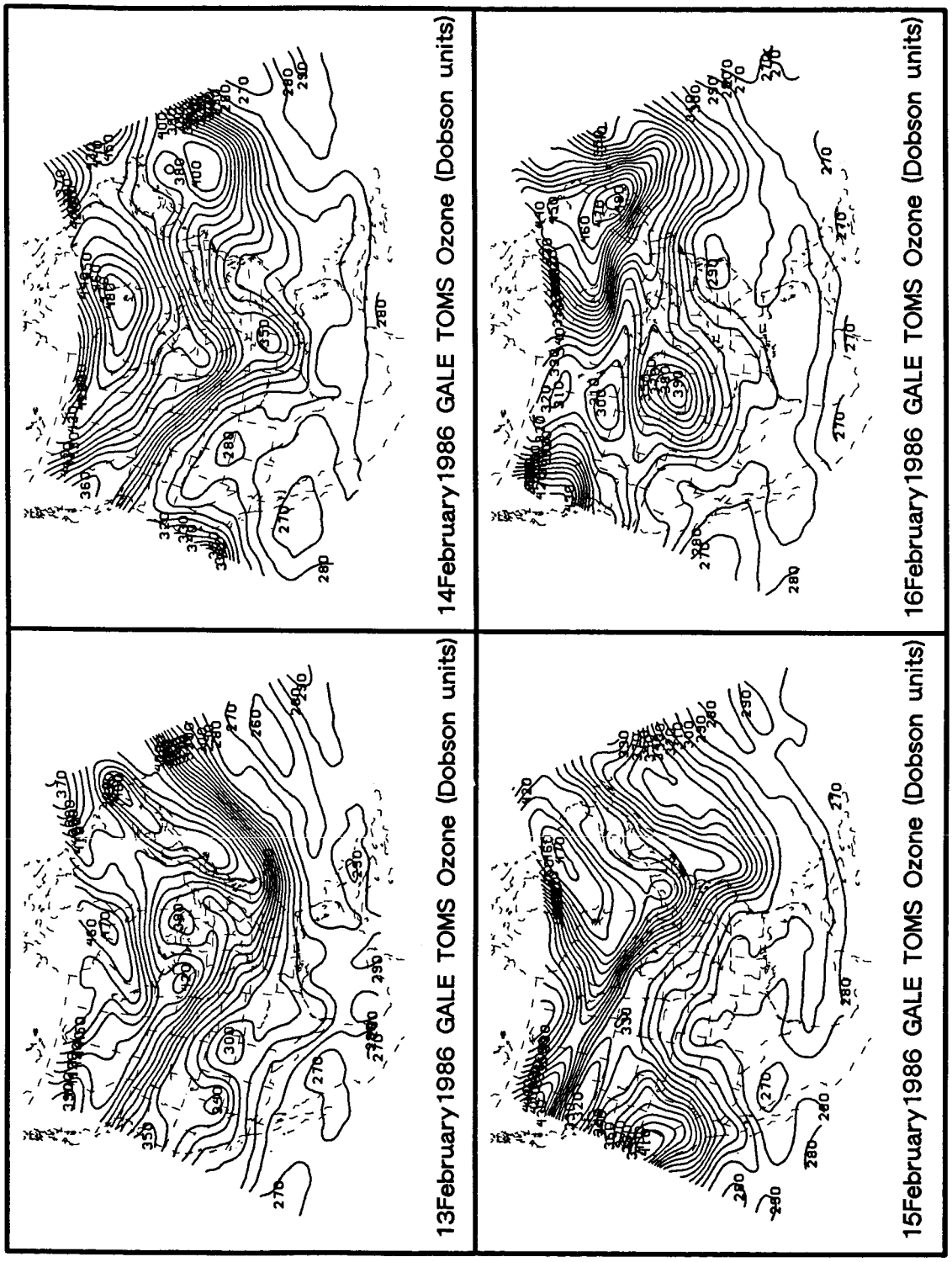

Figure 73. Ozone contour maps (ten Dobson unit intervals) from 13 February through 16 February 1986 covering GALE IOP 6.

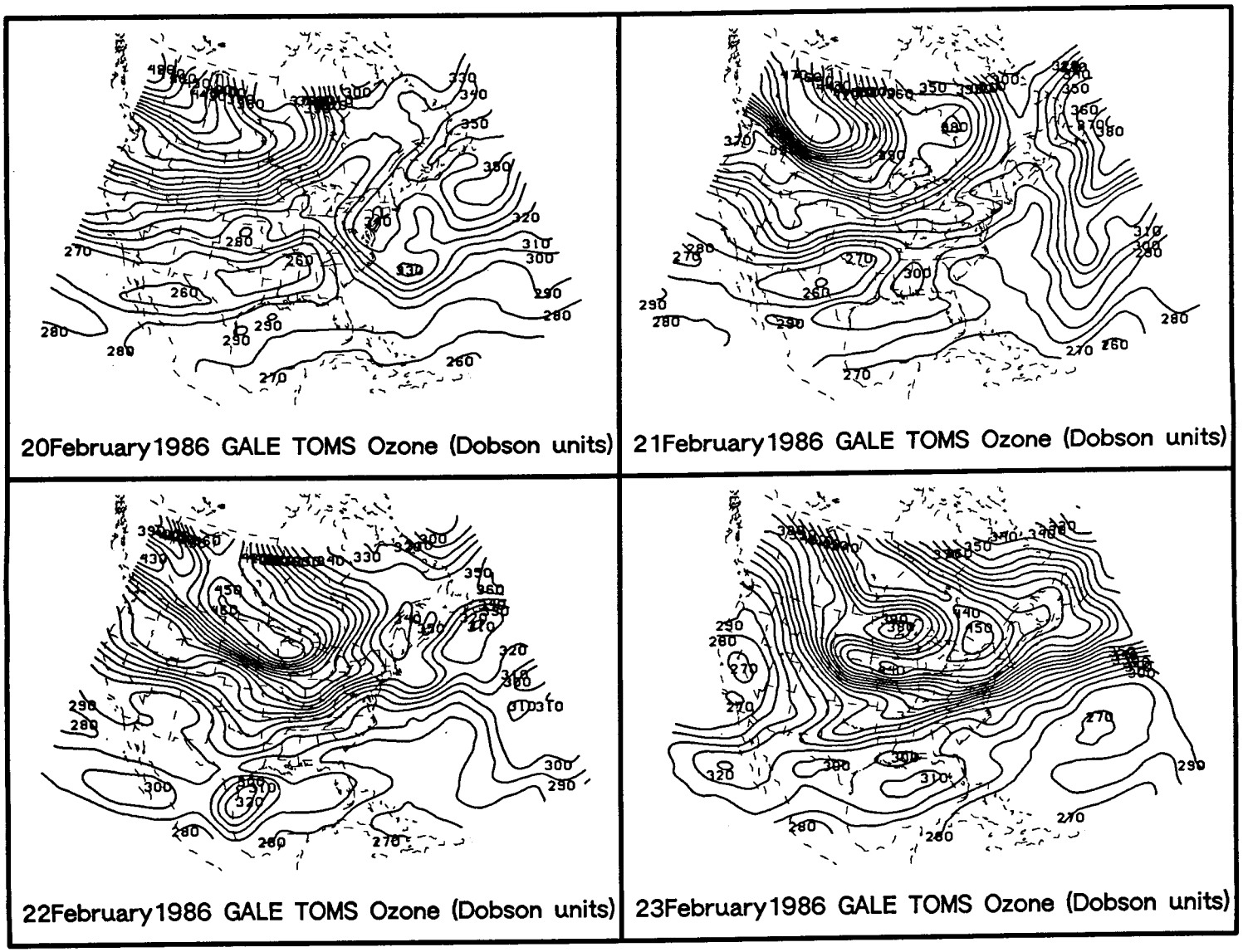

Figure 74. Ozone contour maps (ten Dobson unit intervals) from 20 February through 23 February 1986 covering GALE IOP's 7 and 8.

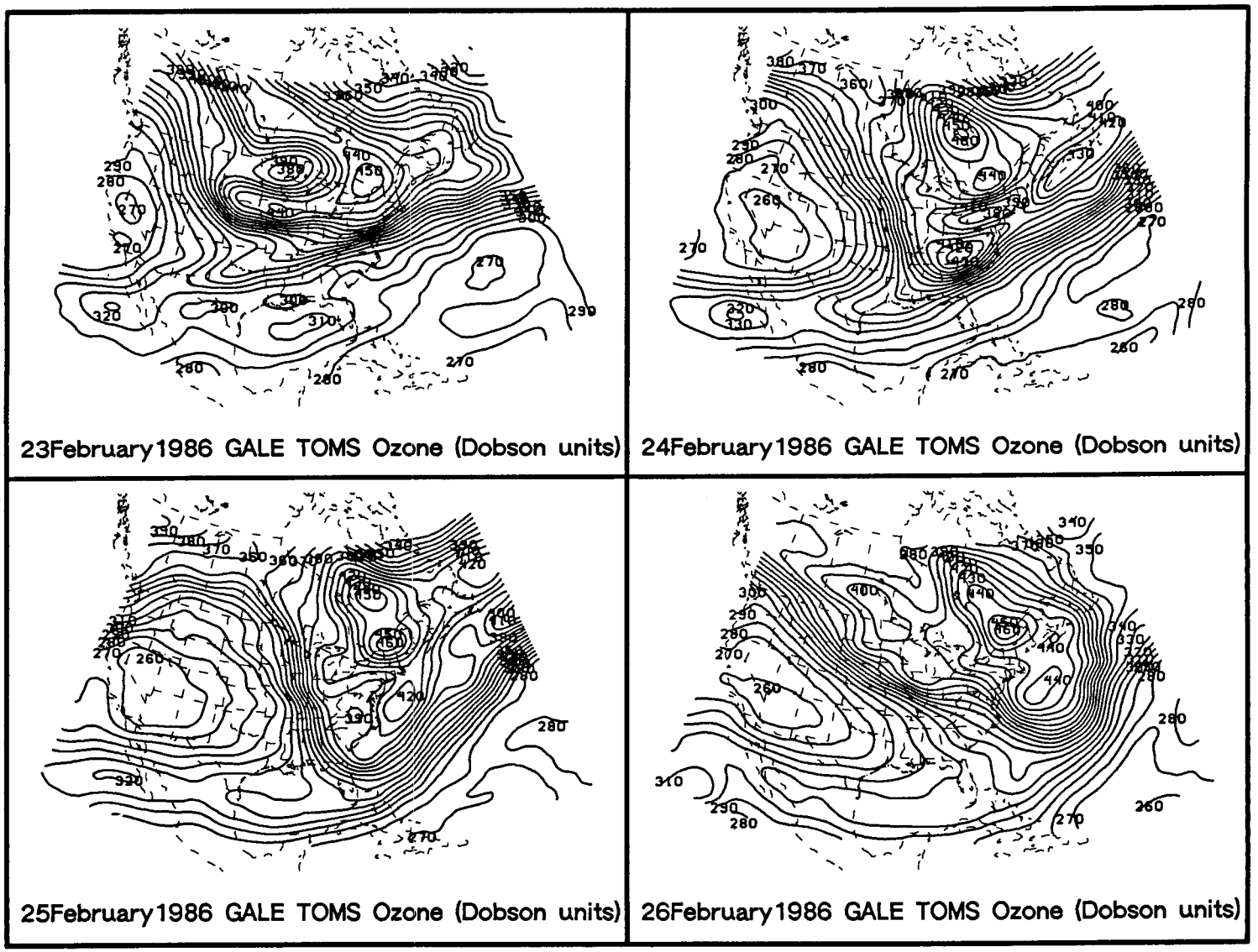

Figure 75. Ozone contour maps (ten Dobson unit intervals) from 23 February through 26 February 1986 covering GALE IOP 9.

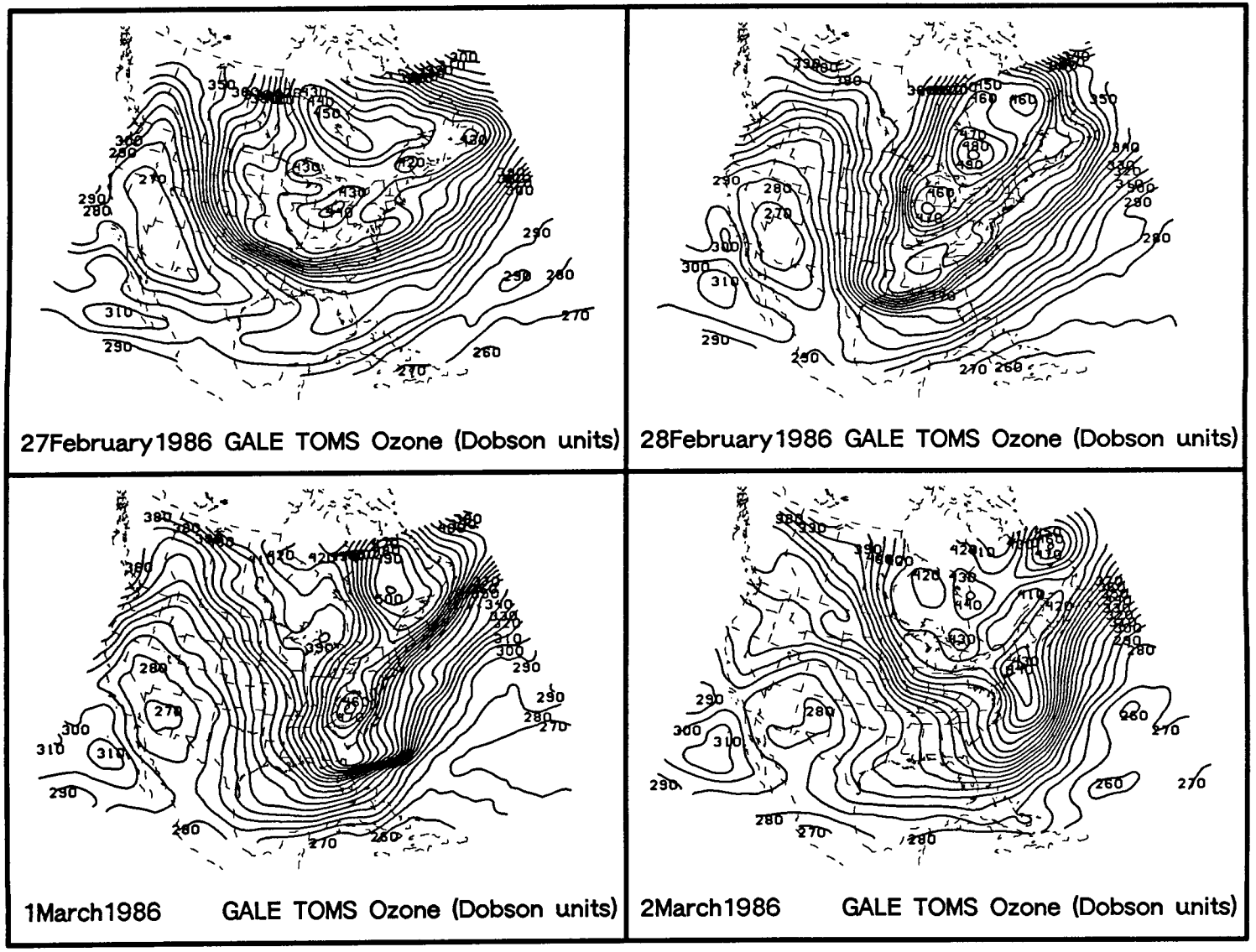

Figure 76. Ozone contour maps (ten Dobson unit intervals) from 27 February through 2 March 1986 covering GALE IOP's 10 and 11.

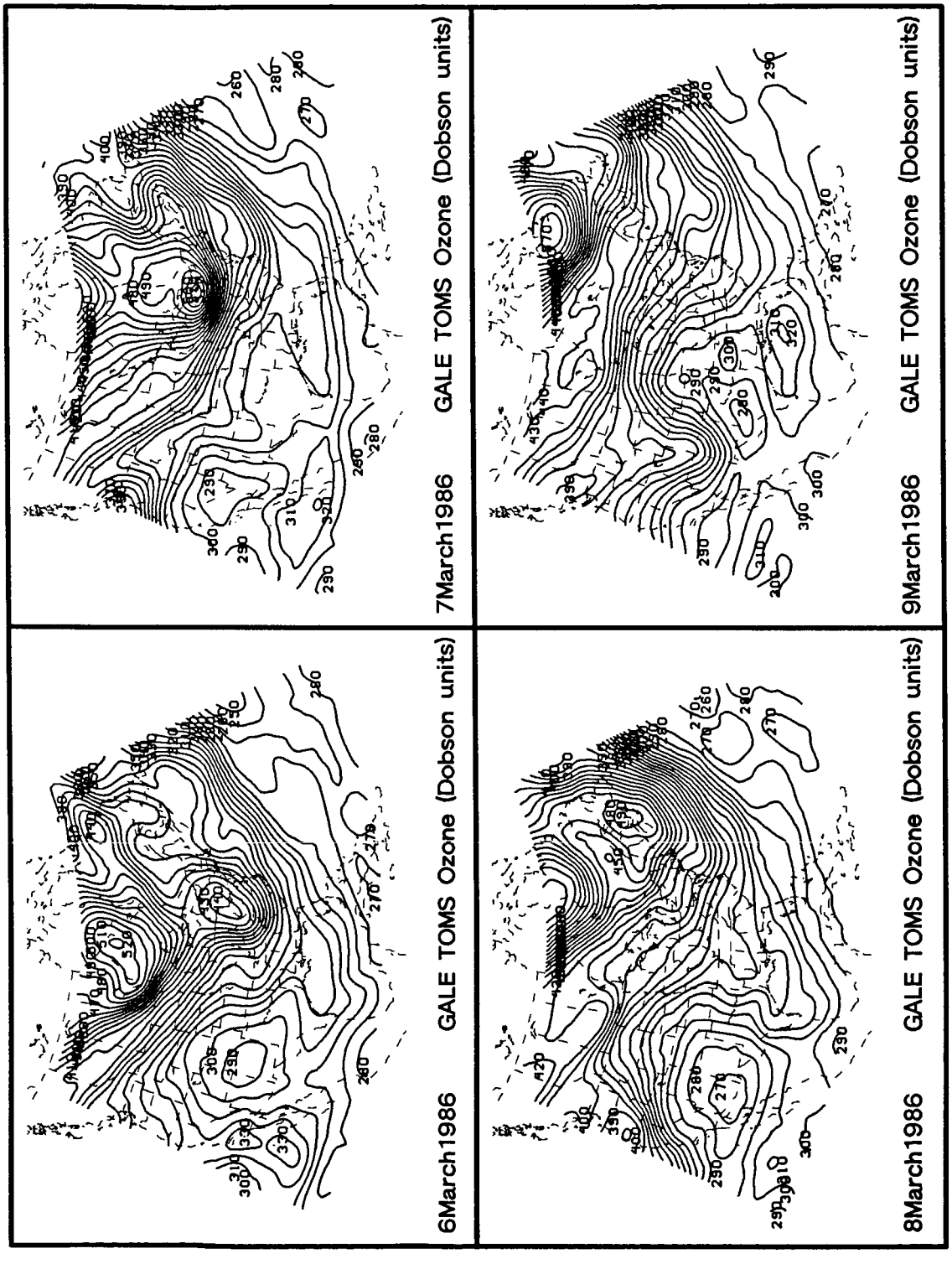

Figure 77. Ozone contour maps (ten Dobson unit intervals) from 6 March through 9 March 1986 covering GALE IOP 12.

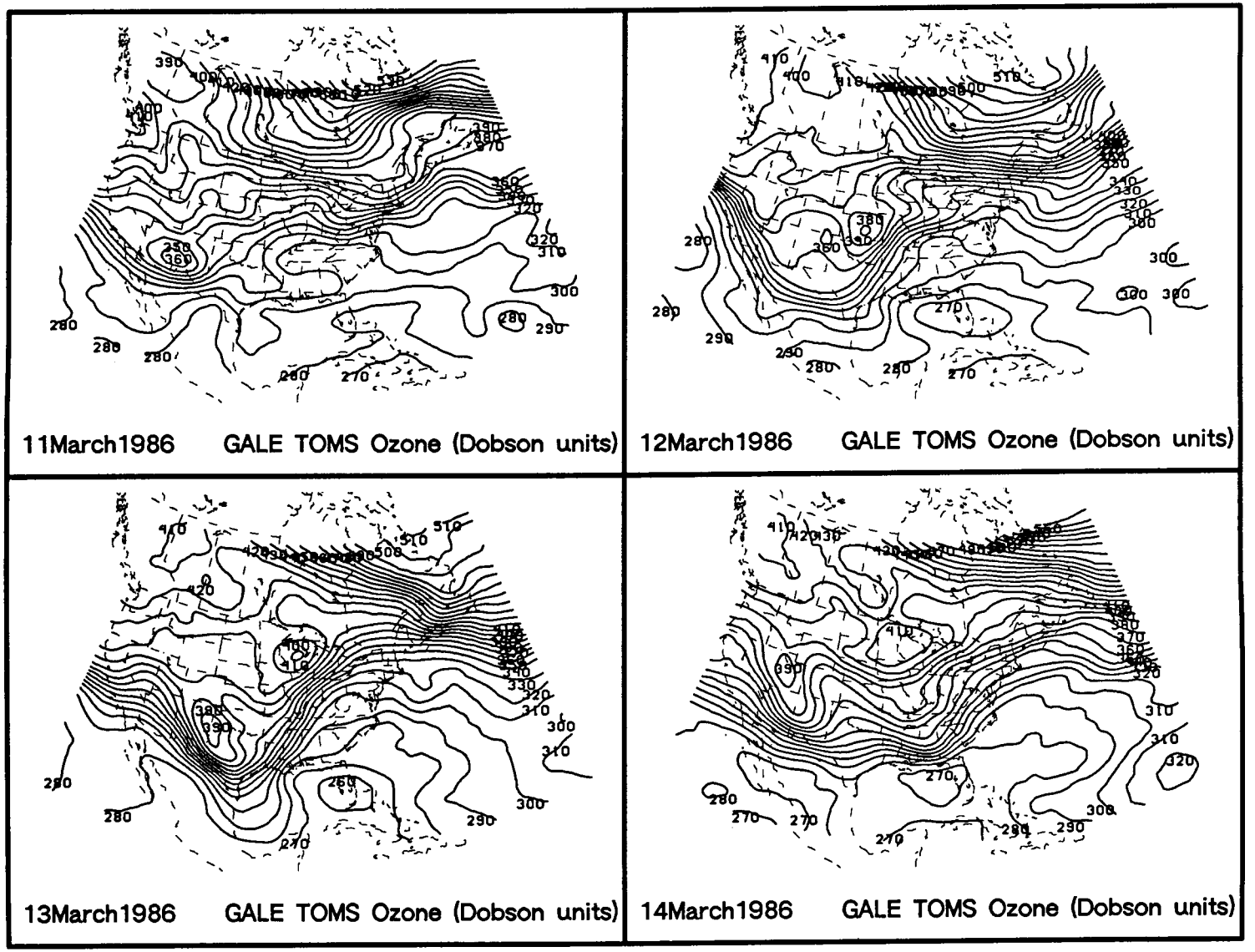

Figure 78. Ozone contour maps (ten Dobson unit intervals) from 11 March through 14 March 1986 covering GALE IOP 13.

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15. Supplementary Notes

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16. Abstract

Data from the TOMS (Total Ozone Mapping Spectrometer) instrument aboard the Nimbus-7 satellite were collected daily in real-time during the GALE (Genesis of Atlantic Lows Experiment) from January 15 through March 15, 1986. The TOMS ozone data values were processed into GEMPAK format and transferred from the Goddard Space Flight Center to GALE Operations in Raleigh-Durham, NC in as little as three hours for use, in part, to direct aircraft research flights recording *in situ* measurements of ozone and water vapor in areas of interest. Once in GEMPAK format, the ozone values were processed into gridded form using the Barnes objective analysis scheme and contour plots of the ozone created. This atlas provides objectively analyzed contour plots of the ozone for each of the sixty days of GALE as well as four-panel presentations of the ozone analyses combined on the basis of GALE Intensive Observing Periods (IOP's).

17. Key Words (Selected by Author(s))	18. Distribution Statement
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